GAS, GASOLINE, AND OIL-ENGINES

INCLUDING

PRODUCER-GAS PLANTS

A COMPLETE AND PRACTICAL WORK TREATING ON

GAS, GASOLINE, KEROSENE, AND CRUDE PETROLEUM OIL-ENGINES, INCLUDING PRODUCER-GAS PLANTS FOR GAS-ENGINE OWNERS, GAS ENGINEERS, AND INTENDING PURCHASERS OF GAS ENGINES, FULLY DESCRIBING AND ILLUSTRATING THE THEORY, DESIGN, CONSTRUCTION, AND MANAGEMENT OF THE EXPLOSIVE MOTOR FOR

STATIONARY, MARINE, AND VEHICLE MOTOR POWER

BY

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Author of "Mechanical Movements," "Compressed Air," etc., etc.

A LIST OF UNITED STATES PATENTS ISSUED ON THE GAS-ENGINE INDUSTRY TO THE PRESENT TIME IS INCLUDED

ILLUSTRATED BY FOUR HUNDRED AND TWELVE ENGRAVINGS

EIGHTEENTH EDITION

REVISED AND ENLARGED

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PREFACE TO THE EIGHTEENTH EDITION

A BOOK representing and illustrating the details of design, manufacture, and management of a new and progressive prime-moving power, falls behind its time by age and therefore needs re-arrangement and additions to bring its text and illustrations up to date in all the departments of such progressive industry.

There is probably no more important mechanical industry, involving the production of motive power for all purposes within the age of steam, than that of the explosive motor and its far-reaching effect in the promotion of industry by a cheap helping hand.

So quickly has this new power expanded to almost universal usefulness as a labor-saving element in the lesser industries, that the literature of the past is found lacking in its up-to-date needs. Progress and improvement are the drift of genius in this advanced age. The progress made in adapting the use of crude petroleum as fuel for explosive power, together with the rapid development of the producer-gas industry, have given a new economy in the production of power, while the use of the hitherto neglected gaseous elements of the blast-furnace and coke manufacture have added new sources of power production at a nominal cost.

With these matters in view the author has revised, rewritten, and added to the contents of the last edition of this work such material and ideals that have come to his knowledge as will better represent the latest standards of construction and operation of the explosive motor; to which is included an illustrated chapter on the production of the new fuel gases and their uses.

The producer, suction, blast-furnace, and coke-oven gases, which are now coming to the front on a large scale for economic power, are included in this work, while crude petroleum and its conversion into power fuel is described and illustrated in the chapter on Oil-Vapor Motors. It has a growing usefulness as the cheapest power fuel where the erection of gas-plants are not convenient.

The insurance interest has formulated rules and regulations for the safe installation of gasoline-motors and producer-gas plants, which are given a place in this edition as a much needed matter of reference.

In the present edition of this book, much new matter has been added, especially to the Marine department. In the past two years, numerous improved patterns have taken the place of the older ones, some of them being entirely new designs for which their advocates claim great advantages. Gas and Gasoline Engines have now reached a high state of perfection in the standard makes.

The Gasoline Engine has almost superseded the windmill for farm and suburban use, and many manufacturers are employing it in preference to electricity for portable machines.

It is estimated that there are about ten thousand manufacturers building Gas, Gasoline, and Oil Engines in the United States, so that with the great variety of styles and makes, the user is now able to select the kind most suitable for his special needs.

The co-operation of the user and the manufacturer has helped to rectify many defects.

The Gas or Gasoline Engine of to-day can be successfully operated by the novice, and many new appliances are here shown which go a long way toward helping the user to avoid trouble.

The list of patents has also been carefully revised so as to include the most recent. The publishers have had the work entirely reset from new type, and have added several hundred new illustrations. The entire book has therefore been brought up to date.

THE AUTHOR.

JANUARY, 1910.

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CHAPTER I

INTRODUCTION

Much attention is now being given by mechanical engineers to the economical results that may be developed in the working of gas, gasoline, and oil-engines for higher powers from producer and other cheap gases and from petroleum and its products. In an economical sense, for small and intermediate power, steam has been left far behind.

It now becomes a question as to how to adapt the design of the new prime mover to a wider range of usefulness and economy.

The best condensing steam-engines now made run with a consumption of about one and one-quarter pounds of coal per horse-power hour; while from two and one-half to seven pounds is the cost per horse-power hour in the various kinds of non-condensing engines now in use. This only covers the cost of fuel; the attendance required in the use of small steam-power is often far greater in cost than the fuel.

When we come to require the larger powers by steam, in which economy may be obtained by compounding and condensing, the facility for obtaining the requisite water-supply is often a bar to its use. The direction in which lies the line of improvement for larger powers with the utmost economy, is as yet a mooted point of discussion in engineering construction, as to steam or explosive-motor power.

The expansion of single-cylinder dimensions for explosive motors, involves practical problems in the progress of ignition of the charge, as well as the thoroughness of mixture of the combustibles; the interference of the products of the previous combustion by producing areas of imperfect mixture or stratification, as discussed in the earlier publications, and which are not yet fully solved; but good progress has been made in this line.

The enlargement of cylinder-area is a source of engine-friction

economy, while, on the contrary, the multiplication of cylinders involves numbers and complexity of moving parts, which go to make disparity between the indicated and brake horse-power, which is the measure of machine efficiency.

An impulse at every stroke, so desirable in an explosive motor and so satisfactorily carried out in the steam-engine, seems to have as yet but a limited counterpart in the explosive motor, as trials of motors with explosion at every stroke have not yet proved entirely satisfactory in service, although double-acting motors are in use, and in order to accomplish fully the desired result, resort has been had to the duplication of single-acting cylinders. This class of explosive-motors seem to fill the bill in effect; yet the complication of a two-cylinder engine as a moving mechanism must compete with a single-cylinder steam-engine.

The principle types of explosive motors seem to have gone through a series of practical trials during the past thirty-five years, which have finally reduced the principles of action to a few permanent forms in the design of motors that have shown by their long-continued use the prospect of their staying qualities and efficiency.

For a gas, gasoline, or oil-explosive power to approximate an ideal standard as a prime mover, it should be simple in design and not liable to get out of order; the parts must be readily accessible, the ignition of the charge must be positive and controllable, the governing close; the motor must run quietly, and must be durable and economical in the use of fuel.

These points of excellence have been striven for by many designers and builders, with varying success; but to get the entire combination without the sacrifice of some good point is not an easy matter.

But for all, the internal-combustion engine has come seemingly like an avalanche of a decade; but it has come to stay, to take its well-deserved position among the powers for aiding labor.

Its ready adaptation to road and marine service has made it a wonder of the age in the development of speed, not before dreamed of as a possibility; yet in so short a time, its power for speed has taken rank on the common road against the locomotive on the rail with its century's progress.

HISTORICAL

Although the ideal principle of explosive power was conceived some two hundred years since, and experiments made with gunpowder as the explosive element, it was not until the last years of the eighteenth century that the idea took a patentable shape, and not until about 1826 (Brown's gas-vacuum engine) that a further progress was made in England by condensing the products of combustion by a jet of water, thus creating a partial vacuum.

Brown's was probably the first explosive engine that did real work. It was clumsy and unwieldy and was soon relegated to its place among the failures of previous experiments. No approach to active explosive effect in a cylinder was reached in practice, although many ingenious designs were described, until about 1838 and the following years. Barnett's engine in England was the first attempt to compress the charge before exploding. From this time on to about 1860 many patents were issued in Europe and a few in the United States for gas-engines, but the progress was slow, and its practical introduction for power came with spasmodic effect and low efficiency. From 1860 on, practical improvement seems to have been made, and the Lenoir motor was produced in France and brought to the United States. It failed to meet expectations, and was soon followed by further improvements in the Hugon motor in France (1862), followed by Beau de Rocha's four-cycle idea, which has been slowly developed through a long series of experimental trials by different inventors. In the hands of Otto and Langdon a further progress was made, and numerous patents were issued in England, France, and Germany, and followed up by an increasing interest in the United States, with a few patents.

From 1870 improvements seem to have advanced at a steady rate, and largely in the valve-gear and precision of governing for variable load.

The early idea of the necessity of slow combustion was a great drawback in the advancement of efficiency, and the suggestion of de Rocha in 1862 did not take root as a prophetic truth until many failures and years of experience had taught the fundamental axiom

Thus the incentive to invention has been the father to a fast-growing industry that has ameliorated and will continue to ameliorate the labor and cost of power for all purposes.

The kerosene-oil engine although tardy in its development, due to tenacity of the fuel, is now so perfected as to take a prominent place for all power purposes within the range of its application, and passing all other fuel types in the economy of its power.

Crude petroleum is on trial for power-fuel, with undoubted economy as to cost, but its mixed constituents are not as satisfactory to manage as the refined product; yet crude-oil motors are in use and their improvement is progressive.

The sporting world has been given a new phase in its possibilities for racing speed from the power and adaptability of the explosive motor.

To make the automobile speed on a good common road range in a parallel with that of the steam-locomotive on steel rails, is an accomplishment of the last decade and should satisfy the speed appetite of the most reckless riders.

The racing launch has also nearly reached a possible limit of speed due to the application of this new power to marine use.

The amateur craze for motive power seems to have spread with the bicycle pace, until the fever has broken out in a multitude of young machinists with motor proclivities.

The intense interest manifested by inventors and engineers in the new motive power is well shown in the progress of the issue of patents during the past thirty years for explosive motors and parts in the United States.

From three patents in 1875, the number has gradually increased to about eighty per annum in the past few years and numbers a total of over eighteen hundred the present year.

The expiration of patents in Europe and the United States has now cast loose many of the bonds that have in a measure retarded the freedom of manufacture in the explosive-motor line, so that the fundamental principles of construction are no longer a hindrance to anyone desiring to build a motor without infringing on patents in force.

CHAPTER II

THEORY OF THE GAS AND GASOLINE-ENGINE

THE laws controlling the elements that create a power by their expansion by heat due to combustion, when properly understood, become a matter of computation in regard to their value as an agent for generating power in the various kinds of explosive engines.

The method of heating the elements of power in explosive engines greatly widens the limits of temperature as available in other types of heat-engines. It disposes of many of the practical troubles of hot-air, and even of steam-engines, in the simplicity and directness of application of the elements of power. In the explosive engine the difficulty of conveying heat for producing expansive effect by convection is displaced by the generation of the required heat within the expansive element and at the instant of its useful work. The low conductivity of heat to and from air has been the great obstacle in the practical development of the hot-air engine; while, on the contrary, it has become the source of economy and practicability in the development of the internal-combustion engine.

The action of air, gas, and the vapors of gasoline and petroleum oil, whether singly or mixed, is affected by changes of temperature practically in nearly the same ratio; but when the elements that produce combustion are interchanged in confined spaces, there is a marked difference of effect. The oxygen of the air, the hydrogen and carbon of a gas, or vapor of gasoline or petroleum oil are the elements that by combustion produce heat to expand the nitrogen of the air and the watery vapor produced by the union of the oxygen in the air and the hydrogen in the gas, as well as also the monoxide and carbonic-acid gas that may be formed by the union of the carbon of gas or vapor with part of the oxygen in the air.

The various mixtures as between air and gas, or air and vapor, with the proportion of the products of combustion left in the cyl-

inder from a previous combustion, form the elements to be considered in estimating the amount of pressure that may be obtained by their combustion and expansive force.

The working process of the explosive motor may be divided into three principle types:

1. Motors with charges igniting at constant volume without compression, such as the Lenoir, Hugon, and other similar types now abandoned as wasteful in fuel and effect.

2. Motors with charges igniting at constant pressure with compression, in which a receiver is charged by a pump and the gases burned while being admitted to the motor cylinder.

Types of the Simon and Brayton engine.

3. Motors with charges igniting at constant volume with variable compression. Types of the later two and four-cycle motors with compression of the indrawn charge; limited in the two-cycle type and variable in the four-cycle type with the ratios of the clearance space in the cylinder.

The explosive motor of greatest efficiency.

The phenomena of the brilliant light and its accompanying heat at the moment of explosion have been witnessed in the experiments of Dugald Clerk in England, the illumination lasting throughout the stroke; but in regard to time in a four-cycle engine, the incandescent state exists only one-quarter of the running time. Thus the time interval, together with the non-conductibility of the gases, makes the phenomena of a high-temperature combustion within the comparatively cool walls of a cylinder a practical possibility.

THE ISOTHERMAL LAW

The natural laws, long since promulgated by Boyle, Gay Lussac, and others, on the subject of the expansion and compression of gases by force and by heat, and their variable pressures and temperatures when confined, are conceded to be practically true and applicable to all gases, whether single, mixed, or combined.

The law formulated by Boyle only relates to the compression and expansion of gases without a change of temperature, and is stated in these words:

If the temperature of a gas be kept constant, its pressure or elastic force will vary inversely as the volume it occupies.

It is expressed in the formula $P \times V = C$, or pressure × volume = constant. Hence, $\frac{C}{P} = V$ and $\frac{C}{V} = P$.

Thus the curve formed by increments of pressure during the expansion or compression of a given volume of gas without change of temperature is designated as the isothermal curve in which the volume multiplied by the pressure is a constant value in expansion, and inversely the pressure divided by the volume is a constant value in compressing a gas.

But as compression and expansion of gases require force for their accomplishment mechanically, or by the application or abstraction of heat chemically, or by convection, a second condition becomes involved, which was formulated into a law of thermodynamics by Gay Lussac under the following conditions:

A given volume of gas under a free piston expands by heat and contracts by the loss of heat, its volume causing a proportional movement of a free piston equal to $\frac{1}{273}$ part of the cylinder volume for each degree Centigrade difference in temperature, or $\frac{1}{492}$ part of its volume for each degree Fahrenheit.

With a fixed piston (constant volume), the pressure is increased or decreased by an increase or decrease of heat in the same proportion of $\frac{1}{273}$ part of its pressure for each degree Centigrade, or $\frac{1}{492}$ part of its pressure for each degree Fahrenheit change in temperature.

This is the natural sequence of the law of mechanical equivalent, which is a necessary deduction from the principle that nothing in nature can be lost or wasted, for all the heat that is imparted to or abstracted from a gaseous body must be accounted for, either as heat or its equivalent transformed into some other form of energy.

In the case of a piston moving in a cylinder by the expansive force of heat in a gaseous body, all the heat expended in expansion of the gas is turned into work; the balance must be accounted for in absorption by the cylinder or radiation.

This theory is equally applicable to the cooling of gases by

abstraction of heat or by cooling due to expansion by the motion of a piston.

The denominators of these heat fractions of expansion or contraction represent the absolute zero of cold below the freezing-point of water, and read − 273° C. or − 492.66° = − 460.66° F. below zero; and these are the starting-points of reference in computing the heat expansion in gas-engines.

According to Boyle's law, called the first law of gases, there are but two characteristics of a gas and their variations to be considered, *viz.*, volume and pressure: while by the law of Gay Lussac, called the second law of gases, a third is added, consisting of the

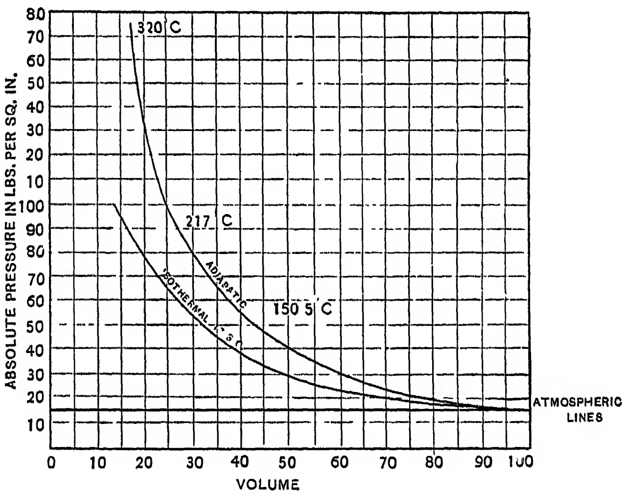


FIG. 1.—Diagram Isothermal and Adiabatic lines.

value of the absolute temperature, counting from absolute zero to the temperatures at which the operations take place.

This is the *Adiabatic* law.

The ratio of the variation of the three conditions—volume, pressure, and heat—from the absolute zero temperature has a certain rate, in which the volume multiplied by the pressure and the product divided by the absolute temperature equals the ratio of expansion for each degree.

If a volume of air is contained in a cylinder having a piston and fitted with an indicator, the piston, if moved to and fro, will alter-

nately compress and expand the air, and the indicator pencil will trace a line or lines upon the card, which lines register the change of pressure and volume occurring in the cylinder. If the piston is perfectly free from leakage, and it be supposed that the temperature of the air is kept quite constant, then the line so traced is called an *Isothermal line*, and the pressure at any point when multiplied by the volume is a constant according to Boyle's law,

$$pv = \text{a constant}.$$

If, however, the piston is moved in very rapidly, the air will not remain at constant temperature, but the temperature will increase because work has been done upon the air, and the heat has no time to escape by conduction. If no heat whatever is lost by any cause, the line will be traced over and over again by the indicator pencil, the cooling by expansion doing work precisely equalling the heating by compression. This is the line of no transmission of heat, therefore, known as *Adiabatic*.

The expansion of a gas $\frac{1}{273}$ of its volume for every degree Centigrade, added to its temperature, is equal to the decimal .00366, the coefficient of expansion for Centigrade units. To any given volume of a gas, its expansion may be computed by multiplying the coefficient by the number of degrees, and by reversing the process the degree of acquired heat may be obtained approximately. These methods are not strictly in conformity with the absolute mathematical formula, because there is a small increase in the increment of expansion of a dry gas, and there is also a slight difference in the increment of expansion due to moisture in the atmosphere and to the vapor of water formed by the union of the hydrogen and oxygen in the combustion chamber of explosive-engines.

The ratio of expansion on the Fahrenheit scale is derived from the absolute temperature below the freezing-point of water (32°) to correspond with the Centigrade scale; therefore $\frac{1}{492.66} = .0020297$, the ratio of expansion from 32° for each degree rise in temperature on the Fahrenheit scale.

As an example, if the temperature of any volume of air or gas at constant volume is raised, say from 60° to 2000° F., the increase in temperature will be 1940°. The ratio will be $\frac{1}{520.66} = .0019206$.

Then by the formula:

Ratio × acquired temp. × initial pressure = the gauge pressure; and $.0019206 \times 1940° \times 14.7 = 54.77$ lbs.

By another formula, a convenient ratio is obtained by $\frac{\text{absolute pressure}}{\text{absolute temp.}}$ or $\frac{14.7}{520.66} = .028233$; then, using the difference of temperature as before, $.028233 \times 1940° = 54.77$ lbs. pressure.

By another formula, leaving out a small increment due to specific heat at high temperatures:

$$\text{I. } \frac{\text{Atmospheric pressure} \times \text{absolute temp.} + \text{acquired temp.}}{\text{Absolute temp.} + \text{initial temp.}} =$$

absolute pressure due to the acquired temperature, from which the atmospheric pressure is deducted for the gauge pressure.

Using the foregoing example, we have $\frac{14.7 \times 460.66° + 2000°}{460.66 + 60°}$ $= 69.47 - 14.7 = 54.77$, the gauge pressure, 460.66 being the absolute temperature for zero Fahrenheit.

For obtaining the volume of expansion of a gas from a given increment of heat, we have the approximate formula:

$$\text{II. } \frac{\text{Volume} \times \text{absolute temp.} + \text{acquired temp.}}{\text{Absolute temp.} + \text{initial temp.}} = \text{heated volume.}$$

In applying this formula to the foregoing example, the figures become:

$$\text{I.} \times \frac{460.66° + 2000°}{460.66 + 60°} = 4\ 72604 \text{ volumes.}$$

From this last term the gauge pressure may be obtained as follows:

III. $4.72604 \times 14.7 = 69.47$ lbs. absolute $- 14.7$ lbs. atmospheric pressure $= 54.77$ lbs. gauge pressure; which is the theoretical pressure due to heating air in a confined space, or at constant volume from 60° to 2000° F.

By inversion of the heat formula for absolute pressure we have the formula for the acquired heat, derived from combustion at constant volume from atmospheric pressure to gauge pressure plus atmospheric pressure as derived from Example I., by which the expression

$$\frac{\text{absolute pressure} \times \text{absolute temp.} + \text{initial temp.}}{\text{initial absolute pressure}}$$

$=$ absolute temperature + temperature of combustion, from which

the acquired temperature is obtained by subtracting the absolute temperature.

Then, for Example, $\frac{69.47\times460.66+60}{14.7}=2460.66$, and $2460.66-460.66=2000°$, the theoretical heat of combustion. The dropping of terminal decimals makes a small decimal difference in the result in the different formulas.

HEAT AND ITS WORK

By Joule's law of the mechanical equivalent of heat, whenever heat is imparted to an elastic body, as air or gas, energy is generated and mechanical work produced by the expansion of the air or gas. When the heat is imparted by combustion within a cylinder containing a movable piston, the mechanical work becomes an amount measurable by the observed pressure and movement of the piston.

The heat generated by the explosive elements and the expansion of the non-combining elements of nitrogen and water vapor that may have been injected into the cylinder as moisture in the air, and the water vapor formed by the union of the oxygen of the air with the hydrogen of the gas, all add to the energy of the work from their expansion by the heat of internal combustion.

As against this, the absorption of heat by the walls of the cylinder, the piston, and cylinder-head or clearance walls, becomes a modifying condition in the force imparted to the moving piston.

It is found that when any explosive mixture of air and gas or hydrocarbon vapor is fired, the pressure falls far short of the pressure computed from the theoretical effect of the heat produced, and from gauging the expansion of the contents of a cylinder.

It is now well known that in practice the high efficiency which is promised by theoretical calculation is never realized; but it must always be remembered that the heat of combustion is the real agent, and that the gases and vapors are but the medium for the conversion of inert elements of power into the activity of energy by their chemical union.

The theory of combustion has been the leading stimulus to large expectations with inventors and constructors of explosive motors; its entanglement with the modifying elements in practice has de-

layed the best development in construction, and as yet no positive design of best form or action seems to have been accomplished; although great progress has been made during the past five years in the development of speed, economy, and the size of the individual units of this new power.

One of the most serious entanglements in the practical development of pressure due to the theoretical computations of the pressure value of the full heat is probably caused by imparting the heat of the fresh charge to the balance of the previous charge that has been cooled by expansion from the maximum pressure to near the atmospheric pressure of the exhaust. The retardation in the velocity of combustion of perfectly mixed elements is now well known from experimental trials with measured quantities; but the principal difficulty in applying these conditions to the practical work of an explosive engine where a necessity for a large clearance space cannot be obviated, is in the inability to obtain a maximum effect from the imperfect mixture and the mingling of the products of the last explosion with the new mixture, which produces a clouded condition that makes the ignition of the mass irregular or chattering, as observed in the expansion lines of indicator cards; but this must not be confounded with the reaction of the spring in the indicator.

Stratification of the mixture has been claimed as taking place in the clearance chamber of the cylinder; but this is not satisfactory, in view of the vortical effect of the violent injection of the air and gas or vapor mixture. It certainly cannot become a perfect mixture in the time of a stroke of a high-speed motor of the two-cycle class. In a four-cycle engine, making 300 revolutions per minute, the injection and compression take place in one-fifth of a second—far too short a time for a perfect infusion of the elements of combustion.

In an experimental way, the velocity of explosion of a perfect mixture of 2 volumes of hydrogen and 1 volume of oxygen has been found to approximate 65 feet per second; and for equal volumes of hydrogen and oxygen, 32 feet per second; with 1 volume coal-gas to 5 volumes air, 3¼ feet per second; 1 volume coal-gas to 6 volumes of air, 1 foot per second; and with an increasing proportion of air, 10 to 9 inches per second. These velocities were obtained in tubes fired at one end only. When the ignition was made in a closed tube,

so that compression was produced by the expansion from combustion, the velocity was largely increased: and with compressed mixtures a great increase of velocity was obtained over the above-stated figures, as has been proved in motors running at 2000 revolutions per minute.

The different values of time, pressure, and computed heat of combustion are shown in Table I., and graphically compared in the diagram (Fig. 2).

The mixtures were Glasgow, Scotland, coal-gas and air. The table and the diagram (Fig. 2) make an excellent study of the con-

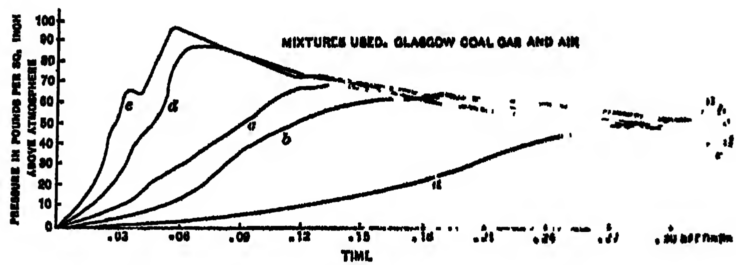


FIG. 2.—Diagram of moments of combustion in a closed chamber, constant volume.

ditions of time and pressure, as well as also of the control of the work of a gas-engine, by varying the proportions of the mixture.

TABLE I.—EXPLOSION AT CONSTANT VOLUME IN A CLOSED CHAMBER.

Diagram curve Fig. 2.	Mixture injected.	Time of explosion. Second.	Gauge pressure Pounds per square inch.	Computed temperature, Fahr.
a	1 volume gas to 13 volumes air.	0.28	52	1,916°
b	1 " " " 11 " "	0.18	63	2,300
c	1 " " " 9 " "	0.13	69	2,523
d	1 " " " 7 " "	0.07	89	3,236
e	1 " " " 5 " "	0.05	96	3,484

The irregularity of the explosive curves in the diagram is fair evidence of imperfect diffusion of the gas and air mixture at the moment of combustion, assuming that the indicator was in perfect action.

Experiments with mixtures of coal-gas and air (Fig. 3), made at

Oldham, England, show a slight variation of effect, which is probably due to different proportions of hydrogen and carbon in the

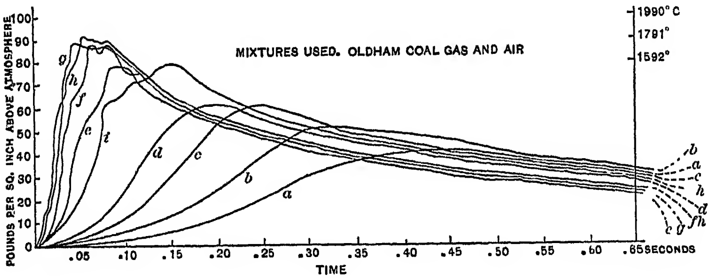


Fig. 3.—Diagram of moments of combustion in a closed chamber, constant volume.

Oldham gas, with the same elements in the Glasgow gas. In Table II. the injection temperature is given, which in itself is not important further than as a basis for computing the theoretical temperature of combustion.

A record of the hygrometric state of the atmosphere in its extremes would be valuable in showing the variation in explosive effect due to the vapor of water derived from the air under different hygrometric conditions.

Table II.—Explosion at Constant Volume in a Closed Chamber.

Diagram curve Fig. 3.	Mixture injected.	Temp. of injection, Fahr.	Time of explosion. Second.	Observed gauge pressure Pounds.	Computed temp. Fahr
a	1 volume gas to 14 volumes air.	64°	0.45	40	1,483
b	1 " " " 13 " "	51	0.31	51 5	1,859
c	1 " " " 12 " "	51	0.24	60.	2,195
d	1 " " " 11 " "	51	0.17	61	2,228
e	1 " " " 9 " "	62	0 08	78.	2,835
f	1 " " " 7 " "	62	0.06	87.	3,151
g	1 " " " 6 " "	51	0.04	90.	3,257
h	1 " " " 5 " "	51	0.055	91.	3,293
i	1 " " " 4 " "	66	0.16	80.	2,871

In an examination of the times of explosion and the corresponding pressures in both tables, it will be seen that a mixture of 1 part gas to 6 parts air is the most effective and will give the highest mean pressure in a gas-engine.

In this diagram the undulations of the rising curves due to irregular firing of the mixture are well marked. There is a limit to the relative proportions of illuminating gas and air mixture that is explosive, somewhat variable, depending upon the proportion of hydrogen in the gas. With ordinary coal-gas, 1 of gas to 15 parts air; and on the lower end of the scale, 1 volume of gas to 2 parts air, are non-explosive. With gasoline vapor the explosive effect ceases at 1 to 16, and a saturated mixture of equal volumes of vapor and air will not explode, while the most intense explosive effect is from a mixture of 1 part vapor to 9 parts air. In the use of gasoline and air mixtures from a carburetter, the best effect is from 1 part saturated air to 8 parts free air.

TABLE III.—PROPERTIES AND EXPLOSIVE TEMPERATURES OF A MIXTURE OF ONE PART OF ILLUMINATING GAS OF 660 THERMAL UNITS PER CUBIC FOOT WITH VARIOUS PROPORTIONS OF AIR WITHOUT MIXTURE OF CHARGE WITH THE PRODUCTS OF A PREVIOUS EXPLOSION.

Proportion, Air to Gas, by Volumes.	Pounds in One Cubic Foot of Mixture.	Specific Heat. Heat Units Required to Raise 1 lb. 1° Fahrenheit. Constant Pressure.	Constant Volume.	Heat to Raise One Cubic Foot of Mixture 1° Fahr.	Heat Units Evolved [illegible]	Ratio, Col. [illegible]	[illegible]	[illegible]
6 to 1....	.074195	.2668	.1913	.014180	94.28	6611.6	[illegible]	[illegible]
7 to 1....	.075012	.2628	.1882	.014116	82	5844.1	.518	3027
8 to 1....	.075647	.2598	.1858	.014059	73.33	5216.1	.513	2832
9 to 1....	.076155	.2575	.1840	.014013	66	4709.9	.50	2637
10 to 1....	.076571	.2555	.1825	.013976	60.	4293	.575	2468
11 to 1....	.076917	.2540	.1813	.013945	55	3944.	.585	2307
12 to 1....	.077211	.2526	.1803	.013922	50.77	3646.7	.58	2115

The weight of a cubic foot of gas and air mixture as given in Col. 2 is found by adding the number of volumes of air multiplied by its weight, .0807, to one volume of gas of weight .035 pound per cubic foot and dividing by the total number of volumes; for example, as in the table $6 \times .0807 = \frac{.5192}{7} = .074195$ as in the first line, and so on for any mixture or for other gases of different specific weight per cubic foot. The heat units evolved by combustion of the mixture (Col. 6) are obtained by dividing the total heat

units in a cubic foot of gas by the total proportion of the mixture, $\frac{660}{7}=94.28$ as in the first line of the table. Col. 5 is obtained by multiplying the weight of a cubic foot of the mixture in Col. 2 by the specific heat at constant volume (Col. 4), $\frac{\text{Col. 6}}{\text{Col. 5}}=\text{Col. 7}$ the total heat ratio, of which Col. 8 gives the usual combustion efficiency – Col. 7 × by Col. 8 gives the absolute rise in temperature of a pure mixture, as given in Col. 9.

The many recorded experiments made to solve the discrepancy between the theoretical and the actual heat development and resulting pressures in the cylinder of an explosive motor, to which much discussion has been given as to the possibilities of dissociation and the increased specific heat of the elements of combustion and non-combustion, as well, also, of absorption and radiation of heat, have as yet furnished no satisfactory conclusion as to what really takes place within the cylinder walls.

There seems to be very little known about dissociation, and somewhat vague theories have been advanced to explain the phenomenon. The fact is, nevertheless, apparent as shown in the production of water and other producer gases by the use of steam in contact with highly incandescent fuel. It is known that a maximum explosive mixture of pure gases, as hydrogen and oxygen or carbonic oxide and oxygen, suffers a contraction of one-third their volume by combustion to their compounds, steam or carbonic acid. In the explosive mixtures in the cylinder of a motor, however, the combining elements form a so small proportion of the contents of the cylinder that the shrinkage of their volume amounts to no more than three per cent. of the cylinder volume. This by no means accounts for the great heat and pressure differences between the theoretical and actual effects.

CHAPTER III

THE UTILIZATION OF HEAT AND ITS EFFICIENCY IN EXPLOSIVE MOTORS

THE utilization of heat in any heat-engine has long been a theme of inquiry and experiment with scientists and engineers, for the purpose of obtaining the best practical conditions and construction of heat-engines that would represent the highest efficiency or the nearest approach to the theoretical value of heat, as measured by empirical laws that have been derived from experimental researches relating to its ultimate value. It is well known that the steam-engine returns only from 12 to 18 per cent. of the power due to the heat generated by the fuel, about 25 per cent. of the total heat being lost in the chimney, the only use of which is to create a draught for the fire; the balance, some 60 per cent., is lost in the exhaust and by radiation. The problem of utmost utilization of force in steam has nearly reached its limit.

The internal-combustion system of creating power is comparatively new in practice, and is but just settling into definite shape by repeated trials and modification of details, so as to give somewhat reliable data as to what may be expected from the rival of the steam-engine as a prime mover.

For small powers, the gas, gasoline, and petroleum-oil engines are forging ahead at a rapid rate, filling the thousand wants of manufacture and business for a power that does not require expensive care, that is perfectly safe at all times, that can be used in any place in the wide world to which its concentrated fuel can be conveyed, and that has eliminated the constant handling of crude fuel and water.

The utilization of heat in a gas-engine is mainly due to the manner in which the products entering into combustion are distributed in relation to the movement of the piston.

The investigation of the foremost exponent of the theory of

the explosive motor was prophetic in consideration of the later realization of the best conditions under which these motors can be made to meet the requirements of economy and practicability. As early as 1862, Beau de Rocha announced, in regard to the coming power, that four requisites were the basis of operation for economy and best effect.

1. The greatest possible cylinder volume with the least possible cooling surface.

2. The greatest possible rapidity of expansion. Hence, *high speed.*

3. The greatest possible expansion. *Long stroke.*

4. The greatest possible pressure at the commencement of expansion. *High compression.*

In the two-cycle motors of the early or Lenoir type, the gas or vapor and air mixtures were drawn in during a part of the stroke, fired, expanded with the motion of the piston, and exhausted by the return stroke. The proportions of the indraught to the stroke of the piston, and the volume of the clearance or combustion chamber, as it is usually called, have been subject to a vast amount of experiment and practical trial, in an endeavor to bring the heat value of their power up to its highest possible limit.

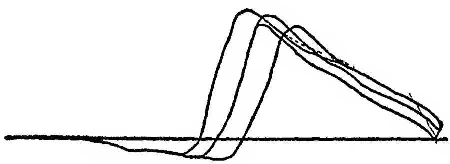


FIG. 4.—Lenoir type of indicator card.

To this class belonged some of the earlier gas-engines; their indicator cards have a typical representation in Fig. 4.

The earlier engines of this class used as high as 96 cubic feet of illuminating gas per horse-power per hour. The consumption of gas fell off by improvements to 70 cubic feet, and finally dropped to 44 and 36 cubic feet per indicated horse-power per hour in the various modifications following the early trials, all of which have dropped out of use.

The efficiency of this class of gas-engines seldom reached 20 per cent. of the heat value of the gas used, while in the compression types of two and four cycle motors there are possibilities of over 40 per cent. The total efficiency of the gas or vapor entering into

combustion in an internal-heat engine is variable, depending upon its constituent-combining elements and the degree of temperature produced. The efficiency due to heat only varies as the difference between the initial temperature of the explosive mixture and the temperature of combustion; and as this varies in actual practice from 1400° to 2500° F., then the reciprocal of the absolute heat of the initial charge, divided by the assumed heat of combustion, would represent the total efficiency. The formula $\frac{H-H'}{H}$ represents this condition, "in which H is the absolute heat of combustion, and H' is the absolute initial temperature," so that, if the operation of the heat cycle was between 60° and 1400° F., the equation would be $\frac{60+460}{1400+460}=.279$ and $1-.279=.72$ per cent. But this cannot represent a working cycle from the change in the specific heat of the gaseous contents of a cylinder while undergoing expansion by the movement of a piston.

The specific heat of air at constant volume is .1685, and at constant pressure is .2375. Their ratio $\frac{.2375}{.1685}=1.408$. The ratios of the other elements entering into combustion in a gas-engine are slightly less than for air; but the ratio for air is near enough for all practical operations. The formula for the application of the condition of work with complete expansion is $1-\left(1.408\frac{H'}{H}\right)$; or, as for above example, $1-\left(1.408\frac{60+460}{1400+460}\right)=.3928$, and $1-.3928=.6071$, or 60 per cent.

As the temperature cannot be utilized for work from the excess of heat in the products of combustion when the expansion has reached the atmospheric line, then the practical amount of expansion and the heat of combustion at the point of exhaust must be considered. In practice, the measured heat of the exhaust at atmospheric pressure, plus the additional heat due to the terminal pressure, becomes a factor in the equation; and, assuming this to be 950° F. in a well-regulated motor, the equation for the above example becomes $1-\left(1.408\times\frac{950-460}{1400-460}\right)=\frac{490}{940}=.521\times1.408=.733$, and

$1-.733=.26$, or an efficiency of 26 per cent. The greater difference in temperature, other things being equal, the greater the efficiency.

In this way efficiencies are worked out through intricate formulas for a variety of theoretical and unknown conditions of combustion in the cylinder: ratios of clearance and cylinder volume, and the uncertain condition of the products of combustion left from the last impulse and the wall temperature. But they are of but little value, except as a mathematical inquiry as to possibilities. The real commercial efficiency of a gas or gasoline-engine depends upon the volume of gas or liquid at some assigned cost, required per actual brake horse-power per hour, in which an indicator card should show that the mechanical action of the valve gear and ignition was as perfect as practicable, and that the ratio of clearance, space, and cylinder volume gave a satisfactory terminal pressure and com-

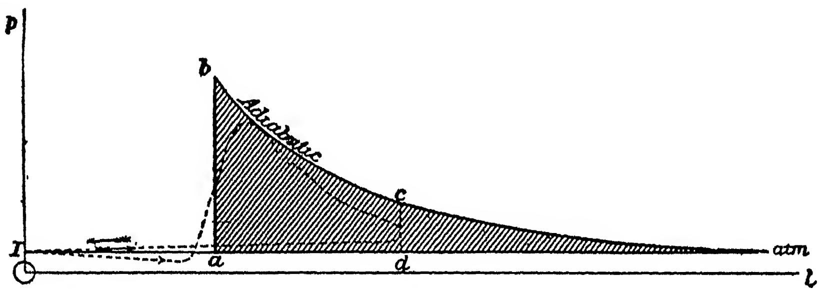


FIG. 5.—Comparative card, Lenoir and perfect expansion.

pression—the difference between the power figured from the indicator card and the brake power being the friction loss of the engine.

In practice, the heat value of the gas per cubic foot may vary from 30 per cent. with illuminating and natural gases to 75 or 80 per cent. as between good illuminating gas and producer gas; then, in order that a given size engine should maintain its rating, a larger volume of a poorer gas should be swept through the cylinder. This requires adjustment of the areas in all the valves to give an explosive motor its highest efficiency for the kind of fuel that is to be used.

The practical effect of the work done by the half-cycle in the earlier type of the two-cycle engine is graphically shown in Fig. 5,

in which *l*, *d* represents the stroke of the piston: the dotted line, the indicator card; and the space in the lines, *a*, *b*, *c*, *d*, the ideal diagram of a perfect gas exhausting at the point *d*, in its incomplete adiabatic expansion. In the valuation of such a card, the depression of the indraught below the atmospheric line and the pressure of the exhaust line should have due consideration as negative quantities to be deducted from the pressure values above the atmospheric line. This class of engines is fast becoming obsolete as a type.

In two-cycle motors of the compression type and in four-cycle motors of the same type, the efficiencies are greatly advanced by compression, producing a more complete infusion of the mixture of gas or vapor and air, quicker firing, and far greater pressure than is possible with the two-cycle type just described.

In the practical operation of the gas-engine during the past twenty years, the gas-consumption efficiencies per indicated horse-power have gradually risen from 17 per cent. to a maximum of 40 per cent. of the theoretical heat, and this has been done chiefly through a decreased combustion chamber and increased compression—the compression having gradually increased in practice from 30 lbs. per square inch to above 100; but there seems to be a limit to compression, as the efficiency ratio decreases with greater increase in compression.

It has been shown that an ideal efficiency of 33 per cent. for 38 lbs. compression will increase to 40 per cent. for 60 lbs., and 43 per cent. for 88 lbs. compression. On the other hand, greater compression means greater explosive pressure and greater strain on the engine structure, which will probably retain in future practice the compression between the limits of 40 and 80 lbs.

In experiments made by Dugald Clerk, in England, with a combustion chamber equal to 0.6 of the space swept by the piston, with a compression of 38 lbs., the consumption of gas was 24 cubic feet per indicated horse-power per hour. With 0.4 compression space and 61 lbs. compression, the consumption of gas was 20 cubic feet per indicated horse-power per hour; and with 0.34 compression space and 87 lbs. compression, the consumption of gas fell to 14.8 cubic feet per indicated horse-power per hour—the actual efficiencies being respectively 17, 21, and 25 per cent. This was with a Crossley four-cycle engine.

In Fig. 6 is represented an ideal card of the work of a perfect compression cycle in which the gases are compressed. Additional pressure is instantly developed by combustion or heat at constant volume, and then allowed to expand to atmospheric pressure—the curves of compression and expansion being adiabatic, as for a dry gas.

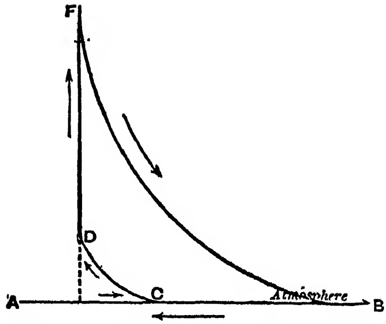


FIG. 6.—Diagram of a perfect cycle with compression.

In this diagram the lines follow Carnot's cycle, in which the whole heat energy is represented in work. The piston stroke commencing at O, compression completed at D, pressure augmented from D to F, expansion doing work from F to B, and exhausting along the atmospheric line B A. The gases in this case expand till their pressure falls to the atmospheric line, and their whole energy is supposed to be utilized. In this imaginary cycle, no heat is supposed to be lost by absorption of walls of a cylinder or by radiation, and no back-pressure during exhaust or friction are taken into account.

The efficiencies in regard to power in a heat-engine may be divided into four kinds, of which

I. The first is known as the *maximum theoretical efficiency* of a perfect engine (represented by the lines in the indicator diagram, Fig. 6). It is expressed by the formula $\frac{T_1 - T_0}{T_1}$ and shows the work of a perfect cycle in an engine working between the received temperature + absolute temperature (T_1) and the initial atmospheric temperature + absolute temperature (T_0).

II. The second is the *actual heat efficiency*, or the ratio of the heat turned into work to the total heat received by the engine. It expresses the *indicated horse-power*.

III. The third is the ratio between the second or *actual heat efficiency* and the first or *maximum theoretical efficiency* of a perfect cycle. It represents the greatest possible utilization of the power of heat in an internal-combustion engine.

IV. The fourth is the *mechanical efficiency*. This is the ratio

between the actual horse-power delivered by the engine through a dynamometer or measured by a brake (brake horse-power), and the indicated horse-power. The difference between the two is the power lost by engine friction.

In regard to the general heat efficiency of the materials of power in explosive engines, we find that with good illuminating gas the practical efficiency varies from 25 to 40 per cent.; kerosene-motors, 20 to 30; gasoline-motors, 20 to 32; acetylene, 25 to 35; alcohol, 20 to 30 per cent. of their heat value. The great variation is no doubt due to imperfect mixtures and variable conditions of the old and new charge in the cylinder; uncertainty as to leakage and the perfection of combustion. In the Diesel motors operating under high pressure, up to nearly 500 pounds, an efficiency of 36 per cent. is claimed.

On general principles the greater difference between the heat of combustion and the heat at exhaust is the relative measure of the heat turned into work, which represents the degree of efficiency without loss during expansion. The mathematical formulas appertaining to the computation of the element of heat and its work in an explosive engine are in a large measure dependent upon assumed values, as the conditions of the heat of combustion are made uncertain by the mixing of the fresh charge with the products of a previous combustion, and by absorption, radiation, and leakage. The computation of the temperature from the observed pressure may be made as before explained, but for compression-engines the needed starting-points for computation are very uncertain, and can only be approximated from the exact measure and value of the elements of combustion in a cylinder charge.

Then theoretically the absolute efficiency in a perfect heat-engine is represented by $\frac{T-T_1}{T}$, in which T is the acquired temperature from absolute zero; T_1, the final absolute temperature after expansion without loss.

Then, for example, supposing the acquired temperature of combustion in a cylinder charge was raised 2000° F. from 60°: the absolute temperature twould be $2000+60+460=2520°$, and if expanded to the initial temperature of 60° without loss the absolute temperature of expansion will be $60+460=520$, then $\frac{2520-520}{2520}=.79$ per

cent., the theoretical efficiency for the above range of temperature. In adiabatic compression or expansion, the ratio of the specific heat of air or other gases becomes a logarithmic exponent of both compression and expansion. The specific heat of air at constant volume is .1685 and at constant pressure, .2375 for 1 lb. in weight; water = 1. for 1 lb. Then $\frac{.2375}{.1685}$ = the ratio y = 1.408.

Then for the following formulas the specific heat $= K_v = .1685$ constant volume, and $K_p = .2375$ constant pressure.

The quantity of heat in thermal units given by an impulse of an explosive engine is $K_v\ (T - t) =$ heat units. Then using the figures as before, $.1685 \times (2520 - 520) = 337$ heat units per pound of the initial charge.

The heat in thermal units discharged will be $K_p\ (T_1 - t)$,

$$T_1 = t\left(\frac{T}{t}\right)^{\frac{1}{y}};$$ t = absolute initial temperature, say 520°.

Then using again the figures as before and assuming that T = 2,520° F., then $T_1 = 520\left(\frac{2520}{520}\right)^{\frac{1}{1.408}} = 520 \times (\log.\ 4.846 \times .7102) =$ 1594° absolute, and 1594 − 520 = 1074° F. Then the heat in thermal units discharged will be $.2375 \times (1594 - 520) = .2375 \times 1074 = 255$ heat units.

With the absolute temperature at the moment of exhaust known, the efficiency of the working cycle may be known, always excepting the losses by convection through the walls of the cylinder.

The formula for this efficiency is: $\text{eff.} = 1 - y\ \frac{T_1 - t}{T - t}$; then by substituting the figures as before, $1 - 1.408\ \frac{1594 - 520}{2520 - 520} = \frac{1074}{2000} = .537 \times 1.408 = .756$, and $1 - .756 = 24$ per cent.

To obtain the adiabatic terminal temperature from the relative volumes of clearance and expansion, we have the formula $\left(\frac{V_0}{V}\right)^{-y-1} = \frac{T_1}{T}$, in which $\frac{V_0}{V}$ is the ratio of expansion in terms of the charging space in engines of the Lenoir type to the whole volume of the cylinder, including the charging space, so that if the stroke of

the piston is equal to the area of the charging or combustion space, the expansion will be twice the volume of the charging space and $\frac{V_0}{V}=\frac{1}{2}$. Then $\frac{T_1}{T}=\left(\frac{1}{2}\right)^{.408}$ and $T_1 = T\left(\frac{1}{2}\right)^{.408}$. Using the same value as before, $T_1=2520\left(\frac{1}{2}\right)^{.408}$ and using logarithms for $\frac{1}{2}$, log. 2 = 0.30103 × .408 = log. 0.12282 = index 1.32, and $\frac{2520°}{1.32}=1908°$, the absolute temperature T_1 at the terminal of the stroke. Then 1908° − 460° = 1448° F., temperature at end of stroke.

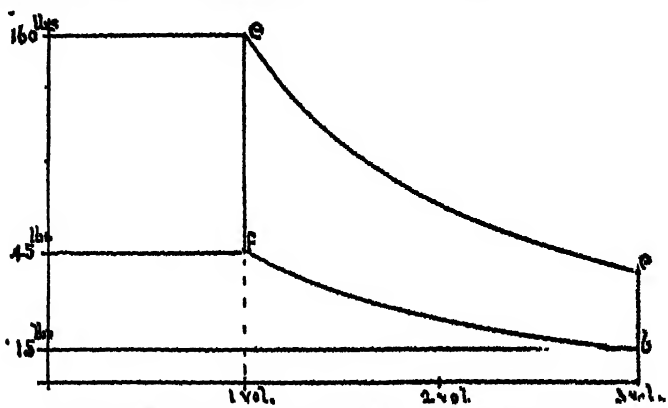


FIG. 7.—The four-cycle compression card. Theoretical.

For obtaining the efficiency from the volume of expansion from a known acquired temperature we have $\frac{V}{V_0}=t=\frac{2}{1}\times 520° = 1040°$ absolute $=t_1$. Then

$$\text{the efficiency} = 1.-\frac{(T_1-t_1)+\gamma(t_1-t)}{T-t}.$$

Then using the values as above,

$$\text{efficiency} = 1.-\frac{(1908-1040)+1.408\,(1040-520)}{2520-520} = 868 + 1.408 \times 520 = 732+868=\frac{1600}{2000}=.80,\text{ and } 1-.80=.20 \text{ per cent.}$$

For a four-cycle compression-engine with compression say to 45 lbs., the efficiency is dependent upon the temperature of compression, the relative volume of combustion chamber and piston stroke, and the temperatures. Fig. 7 is a type card of reference

for the formulas for efficiencies of this class of explosive motors, in which:

t = abs. temp. at *b* normal.
t_c = abs. temp. of compression *f*.
T = abs. acquired temp. *e*.
T_1 = abs. temp. at *c*.
P = abs. pressure at *b*.
P_c = abs. pressure at *f*.
P_0 = abs. pressure at *c*.
V_0 = volume at *b*.
V = volume at *c*.
V_c = volume at *f*.
vo = V or volume at compression = volume at exhaust.
K_v = .1685 specific heat at constant volume.

Let T = abs. acquired temp. = 2520° F. as before.
t = abs. normal temp. = 520° or 60° F.

$$t_c = \text{abs. temp. of compression} = t\left(\frac{P_c}{P}\right)^{\frac{y-1}{y}} = \frac{1.408-1}{1.408} = 0.29.$$

Then $520°\left(\frac{60}{15}\right)^{0.29} = 777°$ absolute temperature of compression.

$$T_1 = \text{abs. temp. of expansion} = \frac{T\,t}{t_c} \text{ or } \frac{2520° \times 520}{777} = 1686°.$$

The terms being assumed and known from assumed data, the efficiency $= 1 - \frac{K_v\,(T-t_c) - K_v\,(T_1-t)}{K_v\,(T-t_c)}$.

Reducing, efficiency $= 1 - \frac{T_1 - t}{T - t_c}$; substituting figures as above found, $1 - \frac{1686-520}{2520-777} = .333$ per cent.; also $1 - \frac{T_1}{T} = \frac{1686}{2520} = .333$ and $1 - \frac{t}{t_c} = \frac{520}{777} = .333$ approximately.

For obtaining the efficiency from the relative volumes at both ends of the piston stroke, with an expansion in the cylinder equal to twice the clearance space, by which the total volume at the end of the stroke will be three times the volume of the clearance space,— efficiency in this case may be expressed by the formula $1 - \left(\frac{V_0}{V_c}\right)^{y-1}$;

substituting, the values become $1-\left(\frac{1}{3}\right)^{.408}$; using logarithms as before, log. $3=0.477121\times.408=0.194665$, the index of which is 1.565, and $\frac{1}{1.565}=.639$. Then $1-.639=.36$ per cent.

TEMPERATURE AND PRESSURES

Owing to the decrease from atmospheric pressure in the indrawing charge of the cylinder, caused by valve and frictional obstruction, the compression seldom starts above 13 lbs. absolute, especially in high-speed engines. Col. 3 in the following table represents the approximate absolute compression pressure for the

TABLE IV.—GAS-ENGINE CLEARANCE RATIOS, APPROXIMATE COMPRESSION, TEMPERATURES OF EXPLOSION AND EXPLOSIVE PRESSURES WITH A MIXTURE OF GAS OF 660 HEAT UNITS PER CUBIC FOOT AND MIXTURE OF GAS 1 TO 6 OF AIR.

Clearance Per Cent. of Piston Volume.	Ratio $\frac{V}{V_c}=\frac{P+C\text{ Vol.}}{\text{Clearance.}}$	Approximate Compression from 13 lbs. Absolute.	Approximate Gauge Pressure.	Absolute Temperature of Compression from 560° F. in Cylinder.	Absolute Temperature of Explosion. Gas, 1 part; Air, 6 parts.	Approximate Explosive Pressure Absolute.	Approximate Gauge Pressure.	[illegible]
1	2	3	4	5	6	7	8	9
		Lbs.		Deg.	Deg.	Lbs.	Lbs.	Deg.
.50	3.	57.	42.	822.	2488	180	141	2027
.444	3.25	65.	50.	846.	2598	197	182	2107
.40	3.50	70.	55.	868.	2638	212	197	2177
.363	3.75	77.	62.	889.	2701	231	219	2240
.333	4.	84.	69.	910.	2751	251	230	2290
.285	4.50	102.	88.	955.	2842	303	288	2381
.25	5.	114.	99.	983.	2901	330	321	2440

clearance percentage and ratio in Cols. 1 and 2, while Col. 4 indicates the gauge pressure from the atmospheric line.

The temperatures in Col. 5 are due to the compression in Col. 3 from an assumed temperature of 560° F. in the mixture of the fresh charge of 6 air to 1 gas with the products of combustion left in the clearance chamber from the exhaust stroke of a medium-speed motor.

This temperature is subject to considerable variation from the difference in the heat-unit power of the gases and vapors used for explosive power, as also of the cylinder-cooling effect.

In Col. 6 is given the approximate temperatures of explosion or a mixture of air 6 to gas 1 of 660 heat units per cubic foot, for the relative values of the clearance ratio in Col. 2 at constant volume.

The formulas for the above approximate table, avoiding decimal values, are as follows:

$$\frac{\text{Col. } 1+1}{\text{Col. } 1}=\text{Col. } 2. \quad 1.35 \log. \frac{V}{V_c}=\log. \frac{p_c}{P}=\text{Col. } 3.$$

$p_c+P=$ absolute pressure Col. 3.

$$.35 \log. \text{Ratio}=\log. \frac{t_c}{t} \text{ Col. } 5.$$

$$\frac{p_cT}{t_c}=P \text{ absolute pressure Col. 7. } P-p=\text{Col. 8. } T-461°=\text{Col. 9.}$$

$p_c=$ absolute pressure of compression.

$p=$ initial absolute pressure in cylinder before compression, 13 lbs.

$P=$ absolute pressure of explosion.

$T=$ absolute explosion temperature.

$t=$ initial absolute temperature in cylinder after charge 560° F.

$t_c=$ absolute temperature of compression.

The explosive absolute temperature in Col. 6 decreases in proportion to the dilution of the gas with air, until with the proportion of 12 air to 1 gas, but 69 per cent. of the temperature given in Col. 6 is available. The decrease in pressure follows in a like proportion.

In Col. 7 is given the absolute explosive pressure due to the conditions in the preceding columns and computed from the formula $\frac{p_cT}{t}=\text{P}$, in which $p_c=$ absolute compression pressure Col. 3. T= absolute explosive temperature Col. 6. $t=$ absolute compression temperature Col. 5, for each ratio in Col. 2.

Col. 8 is the gauge pressure derived from the absolute pressures in Col. 7.

Col. 9 is the explosive temperature on the Fahrenheit scale, T − 461°, or Col. 6 − 461°.

The following table and diagram show the approximate resulting temperatures usual in gas-engines, in consideration of the heat values of each element in the gas and its distribution to the air and heated contents of the clearance space from a previous explosion, and the estimated absorption of heat by the walls of the clearance space at the moment of combustion, for gas of 660 thermal units per cubic foot:

TABLE V.

Clearance Per Cent. of Piston Volume.	Ratio $\frac{P+C}{\text{Clearance}}$.	Usual rise in temperature of explosion of various air and gas mixtures, due to the ratio of compression in column 2						
		6 to 1	7 to 1	8 to 1	9 to 1	10 to 1	11 to 1	12 to 1
.50	3.	2,029	1,922	1,845	1,730	1,629	1,524	1,398
.444	3.25	2,111	2,001	1,918	1,807	1,693	1,581	1,452
.40	3.50	2,183	2,069	1,981	1,868	1,748	1,635	1,500
.363	3.75	2,245	2,127	2,036	1,917	1,795	1,679	1,540
.333	4.	2,300	2,178	2,084	1,961	1,837	1,718	1,578
.285	4.5	2,390	2,269	2,165	2,030	1,907	1,783	1,636
.25	5.	2,462	2,343	2,225	2,098	1,963	1,836	1,683
.222	5.5	2,522	2,404	2,282	2,145	2,008	1,878	1,722
.20	6.	2,572	2,456	2,320	2,180	2,046	1,911	1,755

Diagram of the rise in temperature of various mixtures of air and gas of 660 thermal units per cubic foot at ratios of compression of $\frac{\text{P+C Vol.}}{\text{Clearance Vol.}}$ and of piston-stroke volume, less the estimated loss of temperature due to the clearance volume of a previous combustion and wall-cooling.

The ratio of compression is obtained by the stroke volume of the piston, which may be represented by 1. to which is added the percentage of the volume for clearance, and the sum divided by the clearance equals the *ratio*. For example:

$\frac{1+.50}{.50}=3.$ and $\frac{1+.20}{.20}=6.$ the ratios as in the diagram. Then

CHAPTER IV

RETARDED COMBUSTION, WALL-COOLING, AND COMPRESSION EFFICIENCIES

Some of the serious difficulties in practically realizing the condition of a perfect cycle in an internal-combustion engine are shown in the diagram Fig. 9, taken from an Otto gas engine, in which the cooling effect of the walls is shown by the lagging of the explosion curve, by the missing of several explosions when the cylinder walls have been unduly cooled by the water jacket. The same delay is experienced in starting a gas engine. The indicator card I A D representing the normal condition of constant work in the cylinder; the curve I B D an interruption of explosions for several revolutions; and I C D a still longer interruption in the explosions with the engine in continuous motion.

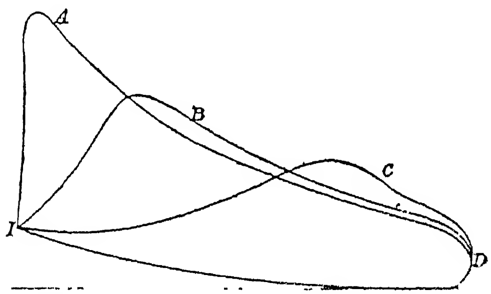


Fig. 9.—Variable card from wall cooling.

In an experimental investigation of the efficiency of a gas-engine under variable piston speeds made in France, it was found that the useful effect increases with the velocity of the piston that is, with the rate of expansion of the burning gases with mixtures of uniform volumes; so that with the variations of time of complete combustion at constant pressure, as illustrated on pages 28-29, and the variations due to speed, in a way compensate in their efficiencies. The dilute mixture, being slow burning, will have its time and pressure quickened by increasing the speed.

TABLE VI.—TRIAL EFFICIENCIES DUE TO INCREASED PISTON SPEED.

$$\text{Efficiency} = \frac{\text{work of indicator diagram}}{\text{theoretical work}}$$

Mixtures	Time of Explosion, Second	Piston speed Foot per Second	Computed work diagram Foot-pounds	Theoretical Work of the gas Foot-pounds	Efficiency
1 volume coal-gas to 9.4 volumes air (.1093 cubic feet mixture)	.53	1.181	70.8	4917	1.44
1 volume coal-gas to 9.4 volumes air	.40	1.64	85.3	4917	1.70
1 " " " " 9.4 " "	.25	3.01	105.5	4917	2.10
1 " " " " 9.4 " "	.16	4.55	125.8	4917	2.60
1 " " " " 6.33 " " (.073 cubic feet mixture)	.15	5.57	127.2	4793	2.60
1 volume coal-gas to 6.33 volumes air	.09	9.51	289.9	4793	6.00
1 " " " " 6.33 " "	.06	14.1	364.4	4793	7.50

These trials give unmistakable evidence that the useful effect increases with the velocity of the piston—that is, with the rate of expansion of the burning gases.

The time necessary for the explosion to become complete and to attain its maximum pressure depends not only on the composition of the mixture, but also upon the rate of expansion.

This has been verified in experiments with a high-speed motor, at speeds from 500 to 1,000 revolutions per minute, or piston speeds of from 16 to 32 feet per second.

The increased speed of combustion due to increased piston speed is a matter of great importance to builders of gas-engines, as well as to the users, as indicating the mechanical direction of improvements to lessen the wearing strain due to high speed and to lighten the vibrating parts with increased strength, in order that the balancing of high-speed engines may be accomplished with the least weight.

From many experiments made in Europe and in the United States, it has been conclusively proved that excessive cylinder cooling by the water-jacket is a loss of efficiency.

In a series of experiments with a simplex engine in France, it was found that a saving of 7 per cent. in gas consumption per brake horse-power was made by raising the temperature of the jacket

water from 141° to 165° F. A still greater saving was made in a trial with an Otto engine by raising the temperature of the jacket water from 61° to 140° F., it being 9.5 per cent less gas per brake horse-power.

In view of the experiments in this direction it clearly shows that in practical work, to obtain the greatest economy per effective brake horse-power, it is necessary:

1st. To transform the heat into work with the greatest rapidity mechanically allowable. This means high piston speed.

2d. To have high initial compression.

3d. To reduce the duration of contact between the hot gases and the cylinder walls to the smallest amount possible; which means short stroke and quick speed, with a spherical cylinder head.

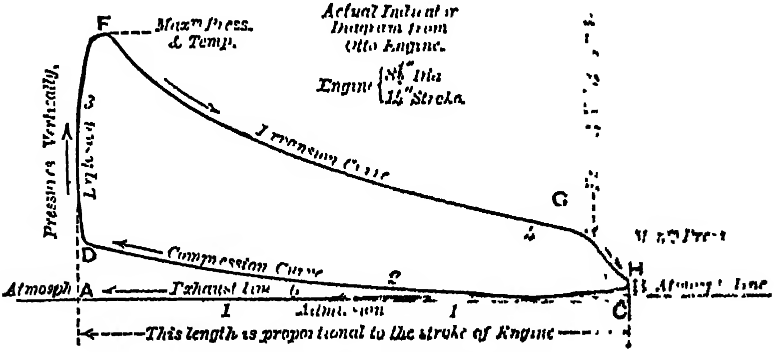


FIG. 10.—Otto four cycle card.

4th. To adjust the temperature of the jacket water to obtain the most economical output of actual power. This means water-tanks or water-coils, with air-cooling surfaces suitable and adjustable to the most economical requirement of the engine, which by late trials requires the jacket water to be discharged at about 200° F.

5th. To reduce the wall surface of the clearance space or combustion chamber to the smallest possible area, in proportion to its required volume. This lessens the loss of the heat of combustion by exposure to a large surface, and allows of a higher mean wall temperature to facilitate the heat of compression.

It will be noticed that the volumes of similar cylinders increase as the cube of their diameters, while the surface of their cold walls

varies as the square of their diameters; so that for large cylinders the ratio of surface to volume is less than for small ones. This points to greater economy in the larger engines.

The study of many experiments goes to prove that combustion takes place gradually in the gas-engine cylinder, and that the rate of increase of pressure or rapidity of firing is controlled by dilution and compression of the mixture, as well as by the rate of expansion or piston speed.

The rate of combustion also depends on the size and shape of the exploding chamber, and is increased by mechanical agitation of the mixture during combustion, and still more by the mode of firing. A small intermittent spark gives the most uncertain ignition, whereas a continuous electric spark passed through an ex-

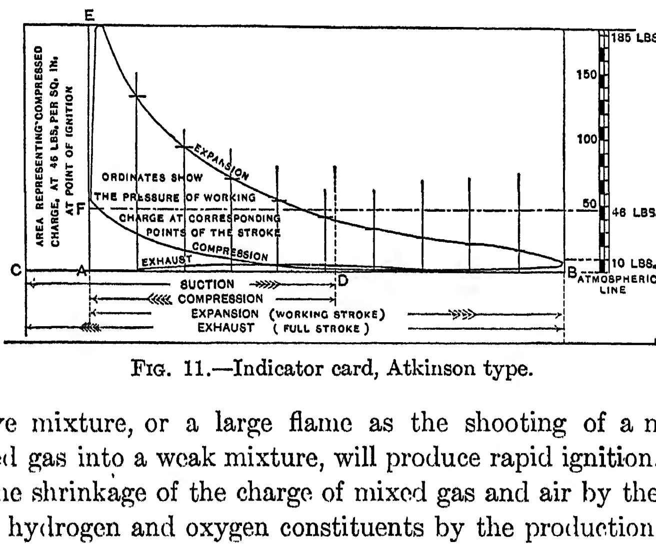


Fig. 11.—Indicator card, Atkinson type.

plosive mixture, or a large flame as the shooting of a mass of lighted gas into a weak mixture, will produce rapid ignition.

The shrinkage of the charge of mixed gas and air by the union of its hydrogen and oxygen constituents by the production of the vapor of water in a gas-engine cylinder, using 1 part illuminating gas to 6.05 parts air, is a notable amount, and of the total volume of 7.05 in cubic feet, the product will be:

1.3714	cubic	feet	water vapor.
.5714	"	"	carbonic acid.
.0050	"	"	nitrogen derived from the gas.
4.8000	"	"	" " " " air.
6.7428	"	"	products of combustion.

Then 7.05 cubic feet of the mixture charge will have shrunk by combustion to 6.7428 cubic feet at initial temperature, or 4.4 per cent.

This difference in the computed shrinkage at initial temperature

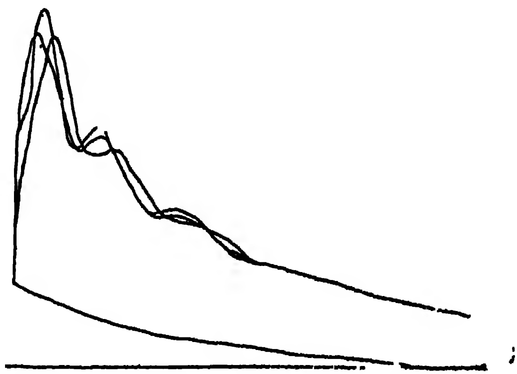


FIG. 12.—Indicator card, full load. Four cycle.

is manifested in the reduced pressure of combustion due to the computed shrinkage, and amounts to about 2 per cent. in the mean pressure, as shown on an indicator card.

With the less rich gas, as water, producer, and Dowson gas, the shrinkage by conversion into water vapor is equal to 5.5 per cent

In Fig. 11 is represented a card from the Atkinson gas engine.

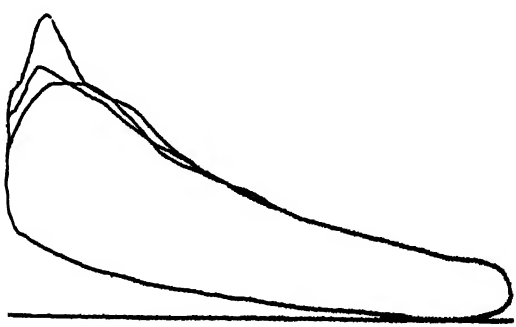


FIG. 13.—Indicator card, half load.

The peculiar design of this engine enables the largest degree of expansion known in gas-engine practice.

In Fig. 12 is shown an actual indicator diagram from an Otto or four-cycle engine, in which the sequences of operation are deline-

ated through two of its four cycles. The curve of explosion shows that firing commenced slightly before the end of the compression stroke, and that combustion lagged until a moment after reversal of the stroke. The expansion line is somewhat higher than the

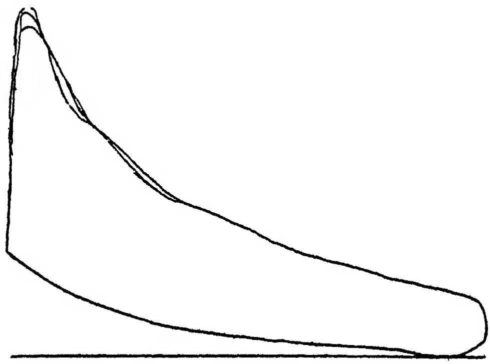


FIG. 14.—Typical compression card. Mean pressure, 76 lbs. per square inch.

adiabatic curve, indicating a partial combustion taking place during the stroke of the piston, showing an irregularity in firing the charge, and probably an irregular progress of combustion by defective mixture. This card was made when running at full load, and computed at 69 lbs. mean pressure.

Fig. 13 represents a card from the same engine at half load and

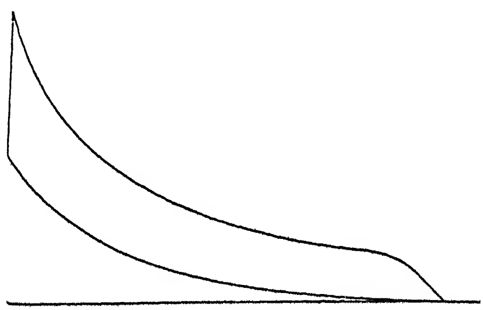


FIG. 15.—Kerosene motor card. Mietz & Weiss.

lessened combustion charge. It shows the same characteristics as to irregularity, and also a lag in firing and a fitful after-combustion; but from weak mixture and interrupted firing the cooling

influence of the cylinder walls has prolonged the combustion with ignition pressure. Mean pressure, about 68 lbs. per square inch.

Fig. 14 represents a typical card of our best compression-engines, with time igniter, at full load and uninterrupted firing.

The kerosene-motor card of the Mietz & Weiss engine (Fig. 15) taken from a 20 horse-power actual, motor with cylinder 12 inches × 12 inches, at 300 revolutions per minute, shows a compression of nearly one-half the explosive force. Its efficiency is very high, and by test gave 21½ horse-power from 16½ pints of oil per hour.

A most unique card is that of the Diesel motor (Fig. 16), which involves a distinct principle in the design and operation of internal-combustion motors, in that instead of taking a mixed charge for instantaneous explosion, its charge primarily is of air and its compression to a pressure at which a temperature is attained above the igniting point of the fuel, then injecting the fuel under a still higher

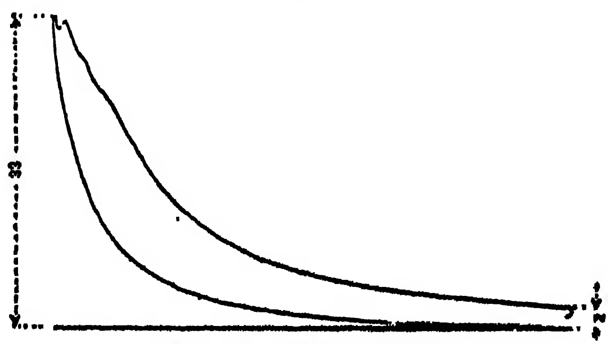


FIG. 16.—Diesel motor card.

pressure by which spontaneous combustion takes place gradually with increasing volume over the compression for part of the stroke or until the fuel charge is consumed. The motor thus operating between the pressures of 500 and 35 lbs. per square inch, with a clearance of about 7 per cent., has given an efficiency of 36 per cent. of the total heat value of kerosene oil.

ADVANCED IGNITION

The governing of an explosive motor, by changing the time of ignition, may be done by advancing or retarding the ignition spark from the dead centre of the stroke.

In Fig. 17 is shown the effect of pre-ignition for regulating speed. The relative areas of the combined card show the change in mean pressure and also the increased compression before the crank ar-

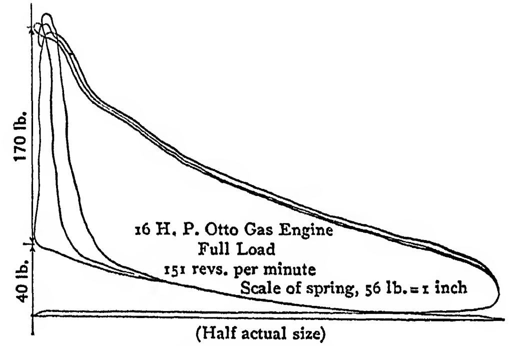


FIG. 17.—Effect of advanced ignition.

rives at its dead centre. This may be carried so far that a reversal of the motor may take place. In some automobile practice both the advance and retardation of ignition is employed in Europe; but is not recommended in lieu of variable-fuel charge.

The value of an indicator card for ascertaining the true condition of the internal activities within the cylinder of an explosive motor is most apparent, and it should always be made the means for finding the cause of trouble that cannot be traced to the outside mechanism.

An indicator card, or a series of them, will always show by its lines the normal or defective condition of the inlet valve and passages; the actual line of compression; the firing moment; the pressure of explosion; the velocity of combustion; the normal or defective line of expansion, as measured by the adiabatic curve, and the normal or defective operation of the exhaust valve, exhaust passages, and exhaust pipe.

In fact, all the cycles of an explosive motor may be made a practical study from a close investigation of the lines of an indicator card.

CHAPTER V

COMPRESSION IN EXPLOSIVE MOTORS, AND ITS WORK

THAT the compression in a gas, gasoline or oil-engine has a direct relation to the power obtained, has been long known to experienced builders, having been suggested by M. Beau de Rocha, in 1862, and afterward brought into practical use in the four-cycle or Otto type about 1880. The degree of compression has had a growth from zero, in the early engines, to the highest available due to the varying ignition temperatures of the different gases and vapors used for explosive fuel, in order to avoid premature explosion from the heat of compression. Much of the increased power for equal-cylinder capacity is due to compression of the charge from the fact that the most powerful explosion of gases, or of any form of explosive material, takes place when the particles are in the closest contact or cohesion with one another, less energy in this form being consumed by the ingredients themselves to bring about their chemical combination, and consequently more energy is given out in useful or available work. This is best shown by the ignition of gunpowder, which, when ignited in the open air, burns rapidly, but without explosion, an explosion only taking place if the powder be confined or compressed into a small space.

In a gas or gasoline-motor with a small clearance or compression space—with high compression—the surface with which the burning gases come into contact is much smaller in comparison with the compression space in a low-compression motor.

Another advantage of a high-compression motor is that on account of the smaller clearance of combustion space less cooling water is required than with a low-compression motor, as the temperature, and consequently the pressure, falls more rapidly. The loss of heat through the water-jacket is thus less in the case of a high-compression than in that of a low-compression motor. In the non-compression type of motor the best results were obtained with a charge of 16 to 18 parts of gas and 100 parts of air, while in the compression type the best results are obtained with an explosive mixture of 7 to 10 parts of gas and 100 parts of air, thus

showing that by the utilization of compression a weaker charge with a greater thermal efficiency is permissible.

It has been found that the explosive pressure resulting from the ignition of the charge of gas or gasoline-vapor and air in the gas-engine cylinder is about $4\frac{1}{2}$ times the pressure prior to ignition. The difficulty about getting high compression is that if the pressure is too high the charge is likely to ignite prematurely, as compression always results in increased temperature. The cylinder may become too hot, a deposit of carbon, a projecting bolt, nut, or fin in the cylinder may become incandescent and ignite the charge which has been excessively heated by the high compression and mixture of the hot gases of the previous explosion.

With gasoline-vapor and air the compression cannot be raised above about 85 pounds to the square inch, many manufacturers not going above 55 or 60 pounds. For natural gas the compression pressure may easily be raised to from 85 to 100 pounds per square inch. For gases of low calorific value, such as blast-furnace or producer-gas, the compression may be increased to from 140 to 190 pounds. In fact the ability to raise the compression to a high point with these gases is one of the principal reasons for their successful adoption for gas-engine use. With kerosene the compression of 250 pounds per square inch has been used with marked economy. Many troubles in regard to loss of power and increase of fuel have occurred and will no doubt continue, owing to the wear of valves, piston, and cylinder, which produces a loss in compression and explosive pressure and a waste of fuel by leakage. Faulty adjustment of valve movement is also a cause of loss of power; which may be from tardy closing of the inlet-valve or a too early opening of the exhaust-valve.

The explosive pressure varies to a considerable amount in proportion to the compression pressure by the difference in fuel value and the proportions of air mixtures, so that for good illuminating gas the explosive pressure may be from 2.5 to 4 times the compression pressure. For natural gas 3 to 4.5, for gasoline 3 to 5, for producer-gas 2 to 3, and for kerosene by injection 3 to 6.

For obtaining the compression clearance we have the equations:

$(p\,v)^{1.35} = (p_1\,v_1)^{1.35}$. Then $p_1 = p\left(\frac{v}{v_1}\right)^{1.35}$ and $v_1 = v\left(\frac{p}{p_1}\right)^{1.35}$ and

substituting values for p, and p_1, we have values for the volume of the clearance, say for 100 pounds gauge pressure of compression, in which v and p represent absolute volumes and pressures.

Then using the expression for pressure, say for 100 pounds, in which p=normal absolute pressure and p_1 = absolute compression pressure, the expression becomes for clearance plus stroke, 1 = $\left(\frac{14.7}{114.7}\right)^{1.35}$ which worked out by logarithms = .1281 log. 1.107549 × 1.35 = $\bar{1}$.14519115 index of which is .1397, the adiabatic ratio of compression for the stroke + clearance, and 1 − .1397 = .8603 the ratio for obtaining the clearance. Then by dividing the stroke in inches by this ratio and subtracting from the quotient the length of the stroke gives the clearance length also in inches.

For example, for 10-inch stroke, $\frac{10}{.8603}$ = 11.623 − 10 = 1.623 inches clearance in the length of a plain cylindrical space for 100 pounds compression. If the clearance space is of other form than the plain extension of the cylinders the volumes will have the same relation.

For example, for 100 pounds compression, a motor with an 8-inch cylinder and 10-inch stroke, the stroke volume will be 502.6 cubic inches, and $\frac{502.6}{.8603}$ = 584.2 cubic inches, and 584.2 − 502.6 = 81.6 cubic inches clearance. From this formula the following table of compression pressures and their clearance ratio in parts of the stroke has been computed:

TABLE VII.—COMPRESSION AND CLEARANCE.

Compression in pounds per square inch.	Ratio. $\frac{\text{Stroke}}{\text{Ratio}}$ − Stroke = Clearance.
100	.8603
90	.8419
80	.8189
70	.7896
60	.7508
50	.6972
40	.6201
30	.5058

The compression temperatures, although well known and easily computed from a known normal temperature of the explosive mixture, are subject to the effect of the uncertain temperature

of the gases of the previous explosion remaining in the cylinder, the temperature of its walls, and the relative volume of the charge, whether full or scant; which are terms too variable to make any computations reliable or available.

For the theoretical compression temperatures from a known normal temperature, we append a table of the rise in temperature for the compression pressures in the foregoing Table VII:

TABLE VIII.—COMPRESSION TEMPERATURES FROM A NORMAL TEMPERATURE OF 60° FAH.

100 lbs. gauge	484°	60 lbs. gauge	373°
90 " "	459	50 " "	339
80 " "	433	40 " "	301
70 " "	404	30 " "	258

To which must be added the assumed temperature of the contents of the cylinder above 60° at the moment that compression begins. For example, for obtaining the assumed temperature at the moment that compression begins for 100 pounds compression and for an observed temperature of the exhaust of 750° F. we have the compression clearance of $.1397 \times 750° = 104.7°$ and piston volume of $.8603 \times 60° = 51.6°$, making the charged temperature 156.3° to which may be added 10° for increase from the walls of the cylinder $= 166° + 484°$ for compression rise $= 650°$ the probable compression temperature for 100 pounds per square inch compression. This is, no doubt, a crude method, but we find nothing better.

The effect of compression on fuel economy is well shown in trials of a four-cycle gas-engine and given in the following table:

TABLE IX.—COMPARISON OF THE THEORETICAL AND ACTUAL EFFICIENCIES OF A FOUR-CYCLE GAS-ENGINE AND FUEL ECONOMY WITH VARYING COMPRESSION.

Compression pressure. pounds.	Ratio of compression.	Computed efficiency from compression volume.	Actual indicated efficiency by card and fuel.	Gas burned per I. H. P.	Ratio of actual to computed efficiency.
				C. ft.	
38	.6	.33	.17	24.	$\frac{.17}{.33} = .51$
61	.4	.40	.21	20.5	$\frac{.21}{.40} = .53$
87	.34	.428	.25	14.8	$\frac{.25}{.428} = .58$

From considerations shown in the table it is evident that there is economy in compression and it is claimed that still higher compression may be used to advantage; but from reasons given in the foregoing discussion of this subject, the practical limit of compression may be stated to be at 100 pounds.

The diagram (Fig. 18), drawn to scale from trials with compressions at 38–61, and 87 pounds, gives an ideal conception of the

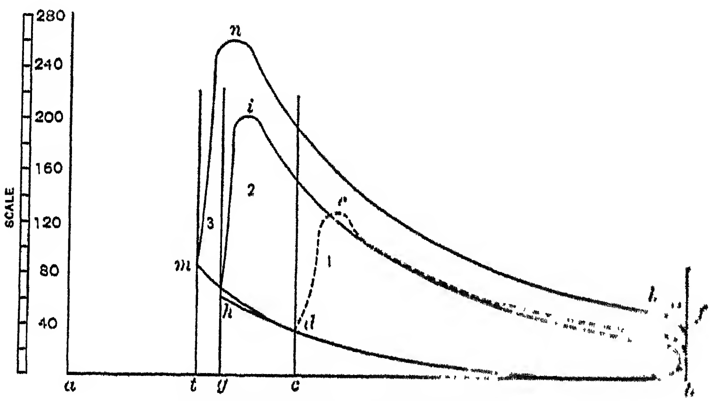


FIG. 18.—Compression diagram.

value of the power of the same engine under various compressions, in which *a*, *b*, represents the piston and clearance space and *b*, *c*; *b*, *g*, and *b*, *l*, the relative piston strokes and clearance for the compressions of 38, 61, and 87 pounds. The relative areas show at a glance and the above table shows the relative value of the fuel consumed per indicated horse-power.

CHAPTER VI

CAUSES OF LOSS AND INEFFICIENCY IN EXPLOSIVE MOTORS

The difference realized in the practical operation of an internal heat engine from the computed effect derived from the values of the explosive elements is probably the most serious difficulty that engineers have encountered in their endeavors to arrive at a rational conclusion as to where the losses were located and the ways and means of design that would eliminate the causes of loss and raise the efficiency step by step to a reasonable percentage of the total efficiency of a perfect cycle.

An authority on the relative condition of the chemical elements under combustion in closed cylinders, attributes the variation of temperature shown in the fall of the expansion curve, and the suppression or retarded evolution of heat, entirely to the cooling action of the cylinder walls, and to this nearly all the phenomena hitherto obscure in the cylinder of a gas-engine.

Others attribute the great difference between the theoretical temperature of combustion and the actual temperature realized in the practical operation of the gas-engine, a loss of more than one-half of the total heat energy of the combustibles, partly to the dissociation of the elements of combustion at extremely high temperatures and their reassociation by expansion in the cylinder, to account for the supposed continued combustion and extra adiabatic curve of the expansion line on the indicator card.

The loss of heat to the walls of the cylinder, piston, and clearance space, as regards the proportion of wall surface to the volume, has gradually brought this point to its smallest ratio in the concave piston-head and globular cylinder-head, with the smallest possible space in the inlet and exhaust passage. The wall surface

of a cylindrical clearance space or combustion chamber of one-half its unit diameter in length is equal to 3.1416 square units, its volume but 0.3927 of a cubic unit; while the same wall surface in a spherical form has a volume of 0.5236 of a cubic unit. It will be readily seen that the volume is increased 33⅓ per cent. in a spherical over a cylindrical form for equal wall surfaces at the moment of explosion, when it is desirable that the greatest amount of heat is generated, and carrying with it the greatest possible pressure from which the expansion takes place by the movement of the piston.

The spherical form cannot continue during the stroke for mechanical reasons; therefore some proportion of piston stroke or cylinder volume must be found to correspond with a spherical form of the combustion chamber to produce the least loss of

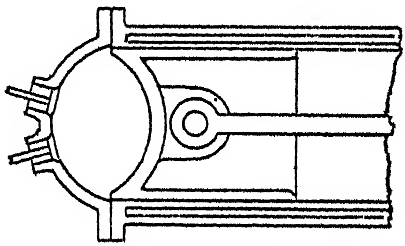


FIG. 19.—Spherical combustion chamber.

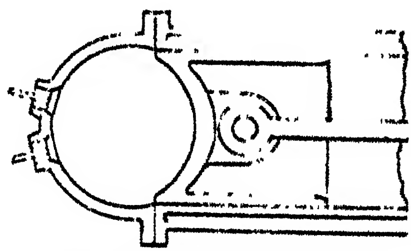


FIG. 20.—Enlarged combustion chamber.

heat through the walls during the combustion and expansion part of the stroke.

This idea we illustrate in Figs. 19 and 20, showing how the relative volumes of cylinder stroke and combustion chamber may be varied to suit the requirements due to the quality of the elements of combustion. In Fig. 18 the ratio may also be decreased by extending the stroke.

Although the concave piston-head shows economy in regard to the relation of the clearance volume to the wall area at the moment of explosive combustion, it may be clearly seen that its concavity increases its surface area and its capacity for absorbing heat, for which there is no provision for cooling the piston, save its contact with the walls of the cylinder and the slight air cooling of its back by its reciprocal motion. For this reason the concave piston-head

has not been generally adopted and the concave cylinder-head, as shown in Fig. 19, with a flat piston-head is the latest and best practice in explosive-engine construction.

The mean temperature of the wall surface of the combustion chamber and cylinder, as indicated by the temperatures of the circulating water, has been found to be an important item in the economy of the gas-engine. Dugald Clerk, in England, a high authority in practical work with the gas-engine, found that 10 per cent. of the gas for a stated amount of power was saved by using water at a temperature in which the ejected water from the cylinder-jacket was near the boiling-point, and ventures the opinion that a still higher temperature for the circulating water may be used as a source of economy.

This could be made practical by elevating the water-tank and adjusting the air-cooling surface so as to maintain the inlet water at just below the boiling-point, and by the rapid circulation induced by the height of the tank above the engine and the pressure, to return the water from the cylinder-jacket a few degrees above the boiling-point.

For a given amount of heat taken from the cylinder by the largest volume of circulating water, the difference in temperature between inlet and outlet of the water-jacket should be the least possible, and this condition of the water circulation gives a more even temperature to all parts of the cylinder; while, on the contrary, a cold-water supply, say at 60° F., so slow as to allow the ejected water to flow off at a temperature near the boiling-point, must make a great difference in temperature between the bottom and top of the cylinder, with a loss in economy in gas and other fuels, as well as in water, if it is obtained by measurement.

In regard to the actual consumption of water per horse-power, and the amount of heat carried off by it, the study of English trials of an Atkinson, Crossley, and Griffin engine showed 62 pounds water per indicated horse-power per hour, with a rise in temperature of 50° F., or 3,100 heat units were carried off in the water out of 12,027 theoretical heat units that were fed to the motor through the 19 cubic feet of gas at 633 heat units per cubic foot per hour.

Theoretically, 2,564 heat units per hour are equal to 1 horse-power. Then 0.257 of the total was given to the jacket water, 0.213

to the indicated power, and the balance, 53 per cent., went to the exhaust, radiation, and the reheating of the previous charge in the clearance and in expanding the nitrogen of the air. Other and mysterious losses, due to the unknown condition of the gases entering into and passing through the heat cycle, which have been claimed and mathematically discussed by authors, have failed to satisfy the practical side of the question, which is the main object of this work.

From the foregoing considerations of losses and inefficiencies, we find that the practice in motor design and construction has not yet reached the desired perfection in its cycular operation. Step by step improvements have been made with many changes in design that may have been without merit as an improvement, further than to gratify the longings of designers for something different from the other thing, and to establish a special construction of their own.

These efforts may in time produce a motor of normal design for each kind of fuel that will give the highest possible efficiency for all conditions of service.

The advent of the speed craze in automobile and marine service has given a great incentive to activity in inventive design in the lines of economy of fuel, stability of action, and lightness of parts so essential to locomotive speed. The progress is apparently slow, yet when compared with the progress of the steam-engine it is a wonder of the past decade.

CHAPTER VII

ECONOMY OF THE GAS-ENGINE FOR ELECTRIC-LIGHTING AND MERITS OF THE TWO TYPES

In the lighting of large dwellings or other buildings, where there is no power used for other purposes, the use of gas, gasoline, or oil-engines for operating an electric generator is not only cheaper in running expenses than the steam-engine, but the comparison holds good for the lighting of towns and villages at the usual cost of gas to consumers; but when the generation of producer-gas can be made for such use on the premises of the electric plant and by the same persons that operate the electric plant, the saving in cost of electric-lighting is several-fold less than by direct gas-burning.

In many towns where oil producer-gas is used, the cost of material used in making the gas is less than thirty-five cents per thousand cubic feet of gas produced. In such places the labor of producing the gas for a town of say fifteen hundred inhabitants is from two to three hours per day, and in some towns, as observed by the author, three hours every other day—giving ample time for the same operator to run the electric plant in the evening, or both may be run simultaneously.

When the mere fact of the cost of gas for direct lighting and its cost for producing the same light by its use in a gas-engine to run an electric generator is considered, the difference in favor of electric-lighting in preference to direct gas-lighting is most apparent.

It has been known for some years that for equal light power but about one-half the volume of gas consumed in direct lighting will produce the same amount of candle-power when used in a gas-engine for generating electricity for lighting.

Again, when we leave the realm of a fixed gas and the cost of its producing-plant, the gasoline and oil-engine again come to the rescue of the fuel element for lighting, from an average cost of 7½ cents per hour for 192 candle-power in lights by direct illumina-

tion, and 2¼ cents for the same amount of light by the use of illuminating gas consumed in a gas-engine with electric generator, to one cent or less by the gasoline and oil-engine for equal light.

In English trials with a Crossley engine of 51 indicated horse-power running a 25½-kilowatt generator (34 electrical horse-power), lighting 400 incandescent lamps (16 candle-power), consumed 1,130 cubic feet illuminating gas per hour, or 2.82 cubic feet of gas per lamp per hour.

The gas used for direct lighting was 16 candle-power at 5 cubic feet per hour. Then, if it had been used for direct lighting, it would have produced $\frac{1130}{5}=226$—16-candle-power gas-lights, a little over one-half the amount of the electric light—or the efficiency of the direct light would have been but 56.5 per cent.

To show the difference between running a gas-engine at full or less than full power, the same engine and generator when running with 300 incandescent lamps (16 candle-power) used 840 cubic feet of gas per hour, and $\frac{840}{5}=168$ 16-candle-power gas-lights, or 56 per cent. efficiency for direct lighting.

When the lamps were cut out to one-half or 200, the consumption of gas was 740 cubic feet per hour, equal to $\frac{740}{5}=148$ gas-lights, with a direct gas-light efficiency of 74 per cent., the difference in efficiency being chiefly due to the constant value of the engine and generator friction in its relation to the variable power.

Another trial with a Tangye engine of a maximum 39 indicated horse-power running an 18.36-kilowatt generator (24.61 electrical horse-power), lighting 300 16-candle-power incandescent lamps, consumed 770 cubic feet illuminating gas per hour. With direct lighting, $\frac{770}{5}=154$ gas-lights (16 candle-power), or an efficiency of 51 per cent. for direct lighting. With 220 incandescent lamps in, 640 cubic feet of gas were consumed per hour, equal to $\frac{640}{5}=128$ gas-lights and a direct gas-light efficiency of $\frac{128}{220}=58$ per cent. Again reducing to 100 lamps, 320 cubic feet of gas were used, equal to 64 gas-lights with an efficiency of 64 per cent. for direct gas-lighting.

It will readily be seen by inspection of these figures that the greatest economy in gas-engine power will be found in gauging the size of a gas-engine by the work it is to do when the work is a constant quantity.

In a trial by the writer of a Nash gas-engine of 5 brake horse-power, driving by belt a Riker 3-kilowatt bipolar generator of 120 volts, 25-ampere capacity, the engine speed was 300 revolutions and the generator 1,400 revolutions per minute; consumption of New York gas, 105 cubic feet per hour. With 50 120-volt A.B.C. lamps in circuit giving a brilliant white light of fully 16 candle-power, the actual voltage by meter was 120, amperage by meter 24, voltage and amperage perfectly steady with continuous running. By turning in resistance and reducing the voltage to 110 and the amperage to 21, the lights were still brilliant in the 50 lamps. With the lamps cut out to 40, the voltmeter vibrated 2 volts and immediately came back to 110 volts, with the amperemeter at 17. With a further and sudden cutting out the light to 20 lamps, the voltage fell to 105 with but slight vibration; amperage, 11. With 15 lamps on, the voltage crept up to 110, amperage 6½; and with 10 lamps only the voltage vibrated for a few seconds and rested at 110, amperage 4½. The engine seemed to answer the change of load remarkably quick, so that there was no perceptible change in speed.

The investment of local lighting-plants by the use of gas, gasoline, and oil-engines in factories and large buildings has been found a great source of economy as against the direct use of municipal electric current or the direct use of gas.

The gasoline or oil-engine makes a most favorable return in economy when used for local lighting as against the prevailing price charged by the operators of large steam-power installations for town and city lighting.

In a trial of eleven days by a 10-horse-power four-cycle gas-engine of the Raymond vertical pattern, belted direct to a 150-light direct-current generator making 1,600 revolutions per minute, with the current measured by a recording wattmeter, giving a steady current to 90 16-candle-power lamps on a factory circuit, the total cost of gas at $1.50 per 1,000 cubic feet with lubricating oils was $20.16. The kilowatts produced by measure were 239.1 at a cost of .0844 cents per kilowatt. The price of the current by the same measure from the electric company was 20 cents per kilowatt—a saving of 57 per cent. In places where gas is $1 per 1,000 feet, the cost would have been only 5¾ cents per kilowatt.

In the lighting of churches the gas or gasoline-engine has been

found to be not only economical, but has largely contributed to the cheerful surroundings of a lighted church at less than one-half the cost of gas for direct lighting, and with no more attention in starting the engine, cleaning, etc., than required for lighting and regulating the ordinary gas-lights.

The last few years have ushered in a most extended use of explosive engines as prime movers for generating the electric current for lighting and the transmission of power. For this purpose the duplex vertical engine and direct-connected multipolar generators are used, from which very favorable results have been obtained. Trials with a 22-brake horse-power two-cylinder vertical engine of the National Meter Co., direct coupled with a 15-kilowatt 6-pole, compound-wound Riker generator, using illuminating gas of 701 thermal units per cubic foot, with engine and generator running at 300 revolutions per minute, are quoted. "The output was 1,312 watts, or equal to 345 lamps of 3.8 watts each = say 16 candle-power, with a total brake horse-power = 22.71. Total consumption of gas per brake horse-power = 17.62 cubic feet. Relative illuminating power of electric light 2.21 as compared with equal consumption by direct gas lighting. Efficiency of engine 20.6 per cent.; efficiency of generator 83.1 per cent."

Statements of still greater economy for lighting by gas and gasoline-engines, in which claims for from 14 to 16 cubic feet of gas and $\frac{1}{8}$ gallon of gasoline per brake horse-power are made for large-sized electric plants, and but a trifle more for smaller sizes. Electric-lighting by the power of the explosive engine is conceded to be economical at all ranges of its power, but with gasoline and oil-vapor the cost of fuel for light drops to less than $\frac{1}{10}$ of a cent per 16-candle-power light per hour.

Electric-lighting plants operated by gas, gasoline, and oil-motors are making rapid advances in the number of units of power, and the small powers of the date of the early edition of this work, have gradually advanced to unit instalments of 100, 500, and 750 horse-power in double and triple-cylinder motors, and by duplicating the motor-units, almost any desired installation can be made on the most economical running basis.

The American practice of construction seems to favor the smaller cylinder volume and their duplication for the higher powers. In

this manner power installations for from 1,000 to 10,000 incandescent lights may be made a most economical plant with illuminating gas, gasoline, producer-gas or petroleum oil.

The extension of electric power for all work by the use of the cheap producer-gas fuel in the explosive motor for generating and transmitting electric current, has taken an advanced position in the manufacturing industry of Europe and the United States, by developing a system of driving machines and tools of all kinds by individual and local motors; thus doing away with a vast amount of running shaft lines and belting with their loss of power.

Marking the rapid progress of events in adapting the explosive motor to the work of high-speed road locomotion and to the propulsion of marine craft and its culmination in racing vehicles and boats that have exceeded in speed, the ardent expectations of the inventors and constructors of the past century, and which has become a marvel of progress in the first years of the new century.

THE TWO-CYCLE AND FOUR-CYCLE TYPES

In the earlier years of explosive-motor progress, was evolved the two types of motors in regard to the cycles of their operation. The early attempts to perfect the two-cycle principle were for many years held in abeyance from the pressure of interests in the four-cycle type, until its simplicity and power possibilities were demonstrated by Mr. Dugald Clerk in England, who gave the principles of the two-cycle motor a broad bearing leading to immediate improvements in design, which has made further progress in the United States, until at the present time it has an equal standard value as a motor-power as its ancient rival the four-cycle or Otto type, as demonstrated by Beau de Rocha in 1862.

Thermodynamically, the methods of the two types are equal as far as combustion is concerned, and compression may favor in a small degree the four-cycle type as well as the purity of the charge.

The cylinder volume of the two-cycle motor is much smaller per unit of power, and the enveloping cylinder surface is therefore greater per unit of volume. Hence more heat is carried off by the jacket water during compression, and the higher compression available from this tends to increase the economy during compression which is lost during expansion.

In the two-cycle motor a scavenging may be obtained to a small extent under the conditions of a crank-chamber pressure charge, while in a four-cycle motor the charge is made by the suction stroke of the main piston and at less than atmospheric pressure, and no scavenging can be made possible except by the momentum of the exhaust in a long exhaust-pipe, which is not always available.

The result of these conditions is that the two-cycle type has a denser charge and a gain in power per unit of volume.

From the above considerations it may be safely stated that a *lower* temperature and higher pressure of charge at the beginning of compression is obtained in the two-cycle motor, greater weight

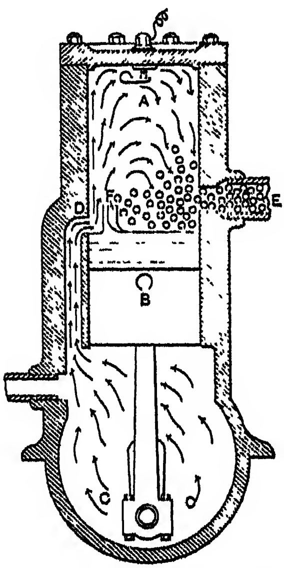


Fig. 21.—Theoretical condition.

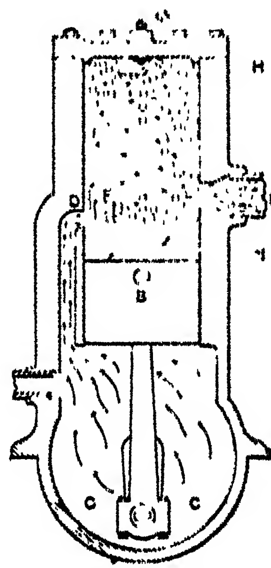


Fig. 22.—Practical condition.

of charge and greater specific power of higher compression resulting in higher thermal efficiency.

The smaller cylinder for the same power of the two-cycle motor gives less friction surface per impulse than of the other type; although the crank-chamber pressure may, in a measure, balance excessive friction of the four-cycle type. Probably the strongest points in favor of the two-cycle type are the lighter fly-wheel and the absence of valves and valve gear, making this type the most simple in construction and the lightest in weight for its developed power.

Yet, for the larger power units, the four-cycle type will no doubt always maintain the standard for efficiency and durability of action.

The distribution of the charge and its degree of mixture with the remains of the previous explosion in the clearance space, has been a matter of discussion for both types of explosive motors, with doubtful results. In Fig. 21 we illustrate what theory suggests

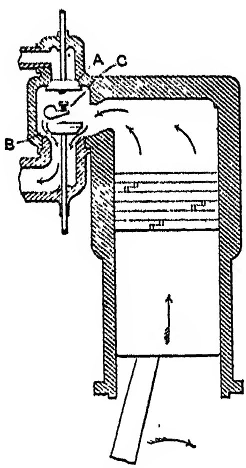


FIG. 23.—Exhaust.

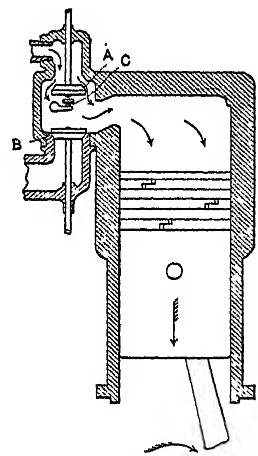


Fig. 24.—New charge.

as to the distribution of the fresh charge in a two-cycle motor, and in Fig. 22 what is the probable distribution of the mixture when the piston starts on its compressive stroke.

The arrows show the probable direction of flow of the fresh charge and burnt gases at the crucial moment.

In Fig. 23 is shown the complete out-sweep of the products of combustion for the full extent of the piston stroke of a four-cycle motor, leaving only the volume of the clearance to mix with the new charge and Fig. 24 the manner by which the new charge sweeps by the ignition device, keeping it cool and avoiding possibilities of pre-ignition by undue heating of the terminals of the sparking device.

Thus, by enveloping the sparking device with the pure mixture, ignition spreads through the charge with its greatest possible velocity, a most desirable condition in high-speed motors with side-valve chambers and igniters within the valve chamber. An igniter in the cylinder-head in this design would be one of the sources of unseen trouble from uncertain ignition.

CHAPTER VIII

THE MATERIAL OF POWER IN EXPLOSIVE ENGINES

The composition of illuminating and producer-gases, alcohol, acetylene, gasoline, kerosene and crude-petroleum oil, and air, as elements of combustion and force in explosive engines, is of great importance in comparison, of heat and motor efficiencies. By reported experiments with 20-candle coal-gas in the United States, by the evaporation of water at 212° F., a cubic foot of gas was credited with 1,236 heat units; while reliable authorities range the value of our best illuminating gases at from 675 to 810 heat units per cubic foot. The specific heat of illuminating gas is much higher than for air, being for coal-gas at constant pressure 0.6844, and at constant volume 0.5196, with a ratio of 1.315; while the specific heat for air at constant pressure is 0.2377, and at constant volume is 0.1688, and their ratio 1.408.

The mixtures of gas and air accordingly vary in their specific heat with ratios relative to the volumes in the mixture. The products of combustion also have a higher specific heat than air, ranging from 0.250 at constant pressure and 0.182 at constant volume, to 0.260 and 0.190 with ratios of 1.37 and 1.36.

A cubic foot of ordinary coal-gas burned in air produces about one ounce of water-vapor and 0.57 of a cubic foot of carbonic-acid gas (CO_2). Its calorific value will average about 675 heat units per cubic foot.

A cubic foot of ordinary coal-gas requires 1.21 cubic feet of oxygen, more or less, due to variation in the constituents of different grades of illuminating gases in various localities, for complete combustion.

Allowing for an available supply of 20 per cent. of oxygen in air for complete combustion, then $1.21 \times 5 = 6.05$ cubic feet of air which is required per cubic foot of gas in a gas-engine for its best work; but in actual practice the presence in the engine cylinder of the products of a previous combustion, and the fact that a sudden

mixture of gas and air may not make a homogeneous combination for perfect combustion, require a larger proportion of air to completely oxidize the gas charge.

It will be seen by inspection of Table II. that the above proportion, without the presence of contaminating elements, produces the quickest firing and approximately the highest pressure at constant volume, and that any greater or less proportion of air will reduce the pressure and the apparent efficiency of an explosive motor. There are other considerations affecting the governing of explosive engines, in which the gas element only is controlled by the governor, requiring an excess of air at the normal speed, so that an economical adjustment of gas consumption may be obtained at both above and below the normal speed.

In Table X the materials of power in use in explosive motors are given with their heat-unit and foot-pound values.

TABLE X.—MATERIAL OF POWER IN EXPLOSIVE ENGINES.

Gases, Vapors, and Other Combustibles.	Heat Units per Pound.	Heat Units per Cubic Foot.	Foot-Pounds per Cubic Foot.
Hydrogen, H.	61,560	293 5	228,343
Carbon, C	14,540		
Crude Petroleum, sp. gr. 0 873.	18,324		
Crude Petroleum, Penn., sp. gr. 0.841.	18,401		
Kerosene, $C_{10}H_{22}$.	22,000		
Benzine, C_6H_6.	18,448		
Gasoline, C_6H_{14}	18,000		
Alcohol Methyl, $C_2H_4O_2$.	20,000		
Denatured Methyl Alcohol.	13,000		
Acetylene, C_2H_2.	21,492	868	675,304
19-can.-power Illuminating Gas.		800	622,400
16- " " " "		665	517,370
15- " " " "		620	482,360
Gasoline Vapor, C_6H_{14}.	18,000	692	538.376
Natural Gas Leechburg, Pa.		1051	817,678
" " Pittsburg, Pa.		892	693,976
Water-Gas, average.		290	225,620
Producer-Gas, 100 to		150	116,700
Suction-Gas, average.		135	105,030
Marsh-Gas, Methane, C.H.	23,594	1051	817,678
Olefiant Gas, Ethylene, C_2H_4.	21,430	1677	1,304,716

The various other gases than coal-gas used in explosive engines are NATURAL GAS, ACETYLENE, liberated by the action of water on calcium carbide; PRODUCER-GAS, made by the limited action of air

alone upon incandescent fuel; WATER-GAS, made by the action of steam alone upon incandescent fuel; SEMI-WATER GAS, made by the action of both air and steam upon incandescent fuel also named DOWSON GAS in England—and SUCTION-GAS. Alcohol is also coming into use in Europe.

NATURAL GAS

The constituents of natural gas vary to a considerable extent in different localities. The following is the analysis of some of the Pennsylvania wells:

TABLE XI.—NATURAL GAS CONSTITUENTS, BY VOLUME.

Constituents.	Olean, N. Y.	Pittsburg, Pa.	Leechburg, Pa.	Harvey Well, Butler County	Burns Well, Butler County.
Hydrogen, H	....	22.00	4.79	13.50	6.10
Marsh-gas, CH_4	96.50	67.00	89.65	80.11	75.44
Ethane, C_2H_4	....	5.00	4.39	5.72	18.12
Heavy hydrocarbons	1.00	1.00	.56		
Carbonic oxide, CO	.50	.60	.26	trace	trace
Carbonic acid, CO_2	....	.60	.35	.66	.34
Nitrogen, N	....	3.00			
Oxygen, O	2.00	.80			
	100.00	100.00	100.00	100.00	100.00
Heat units, cubic foot	1200	892	1051	959	1151

Density, 0.5 to 0.55 (air 1).

The calorific value of natural gas in much of the Western gas fields is below these figures.

In experiments recorded by Brannt, "Petroleum and Its Products," with the *oil-gas* as made for town lighting in many parts of the United States, of specific gravity about 0.68 (air 1), mixtures of oil-gas with air had the following explosive properties:

Oil-gas, volumes.	Air, volumes.	Explosive effect.
1	4.9	None.
1	5.6 to 5.8	Slight.
1	6 to 6.5	Heavy.
1	7 to 9	Very heavy.
1	10 to 13	Heavy.
1	14 to 16	Slight.
1	17 to 17.7	Very slight.
1	18 to 22	None.

It will be seen that mixtures varying from 1 of gas to 6 of air, and all the way to 1 of gas to 13 of air, are available for use in gas-engines for the varying conditions of speed and power regulation; and that 1 of gas to from 7 to 9 of air produces the best working effect. Its calorific value varies in different localities from 600 to 700 heat units per cubic foot. Ordinary oil illuminating gas varies somewhat in its constituents, and may average: Hydrogen, 39.5; marsh-gas, 37.3; nitrogen, 8.2; heavy hydrocarbons, 6.6; carbonic oxide, 4.3; oxygen (free), 1.4; water-vapor and impurities, 2.7; total, 100; and is equal to 617 heat units per cubic foot.

PRODUCER-GAS

The constituents of producer-gas vary largely in the different methods by which it is made; in fact, all of the following described gases are made in producers, so-called. The constituents of the low grade of this name are

Carbonic oxide, CO	22.8	per cent.
Nitrogen, N	63 5	"
Carbonic acid, CO_2	3.6	"
Hydrogen, H	2 2	"
Marsh-gas (methane), CH_4	7.4	"
Free oxygen, O	5	"
	100.0	"

The average heating power of this variety of producer-gas is about 111 heat units per cubic foot.

Another producer-gas called

WATER-GAS

has an average composition of

Carbonic oxide, CO	41	per cent.
Hydrogen, H	48	"
Carbonic acid, CO_2	6	"
Nitrogen, N	5	"
	100	"

and has an average calorific value of 291 heat units per cubic foot.

SEMI-WATER GAS

or, as designated in England, *Dowson gas*, from the name of the inventor of a water-gas making plant, has the following average composition:

Hydrogen, H.	18.73	per cent.
Marsh-gas, (methane), CH_4	.31	"
Olefiant gas, C_2H_4	.31	"
Carbonic oxide, CO	25.07	"
Carbonic acid, CO_2	6.57	"
Oxygen, O.	.03	"
Nitrogen, N.	48.98	"
	100.00	"

It has a calorific value of about 150 heat units per cubic foot.

PETROLEUM PRODUCTS USED IN EXPLOSIVE ENGINES

The principal products derived from crude petroleum for power purposes may commercially come under the names of gasoline, naphtha (three grades, B, C, and A), kerosene, gas-oil, and crude oil.

The first distillate: Rhigoline, boiling at 113° F., specific gravity 0.59 to 0.60; chimogene, boiling at from 122° to 138° F., specific gravity 0.625; gasoline, boiling at from 140° to 158° F., specific gravity 0.636 to 0.657; naphtha "C" (by some also called benzine), boiling from 160° to 216° F., specific gravity 0.66 to 0.70; naphtha "B" (ligroine), boiling at from 200° to 240° F., specific gravity 0.71 to 0.74; naphtha "A" (putzoel), boiling at from 250° to 300° F.

The commercial gasoline of the American trade is a combination of the above fractional distillates, boiling at from 125° to 200° F., specific gravity 0.63 to 0.74.

Kerosene, boiling at from 300° to 500° F., specific gravity 0.76 to 0.80.

Gas-oil, boiling at above 500° F., specific gravity above 0.80.

Crude petroleum. boiling uncertain from its mixed constituents, specific gravity about 0.80.

The vapor of commercial gasoline at 60° F. is equal to 1,200 volumes of the liquid, sustains a water pressure of from 6 to 8

inches, and will maintain a working pressure of 2 inches, or equal to any gas service when the temperature is maintained at 60° F., and with an evaporating surface equal to 5¼ square feet per required horse-power, using proportions of 6 volumes of air to 1 volume of gasoline-vapor.

Commercial kerosene requires a temperature of 95° F. to maintain a vapor pressure of from ¼ to ½-inch water pressure, requiring a much larger evaporating surface than for gasoline. It may be vaporized by heat from the exhaust, and is so used in several types of oil-engines.

TABLE XII.—PERCENTAGE, SPECIFIC GRAVITY, AND FLASHING-POINT OF THE PRODUCTS OF PETROLEUM.

Products.	Per Cent. of Each.	Specific Gravity.	Flashing-Point, F.
Rhigolene and chimogene	trace		
Gasoline } Commercial gasoline	.02	0.650	10°
Benzine naphtha } Commercial gasoline	.10	0 700	14
Kerosene, light } Commercial gasoline	.10	0.730	50
Kerosene, medium	35	0 800	150
Kerosene, heavy	.10	0.890	270
Lubricating oil	10	0 905	315
Cylinder-oil	05	0.915	360
Vaseline	.02	0.925	
Residuum and loss	.16		
	1 00		

GASOLINE

The gasoline of the American trade varies somewhat in specific gravity from 0.70 to 0.74 as measured by the Baumé scale. Seventy is a light grade and 0.74 is termed stove gasoline from its general use for heating.

The analysis of 71 gravity gives carbon, 838; hydrogen, 155; impurities, 007 in 1,000 parts, with a heating value of above 18,000 thermal units per pound.

The variation in gravity of gasoline is due to the percentage of hydrogen. The vapor of gasoline is equal to 160 cubic feet per gallon or about 1,200 times its liquid bulk.

A saturated "air-gas" of equal parts air and vapor equals 320

cubic feet per gallon of liquid. It is non-explosive and much used as an illuminating gas.

Seventy-four gravity gasoline weighs 6.16 pounds per gallon; its pure vapor is 26 cubic feet per pound and $\frac{18,000}{26}$ 692 heat units per cubic foot. The evaporation of gasoline at atmospheric pressure varies approximately as the relative squares of the temperature; so that in summer, with a temperature of 80° F., the evaporation may be four times greater than in winter at a temperature of 40°. Hence a carbureter may do four times as much work in evaporation, without artificial heat, at one time as at another.

Under the varying temperatures to which carbureters are subject from atmospheric and surface conditions, the more evaporating surface the generator presents, the stronger and more uniform will be the quality of the gas furnished.

The boiling-point of gasoline, such as is usually in use for explosive engines, ranges from 150° to 180° F., and the flashing-point of the liquid ranges from 10° to 14° F. The complete combustion of the vapor of gasoline from one pound of the liquid requires 189 cubic feet of air, and as one pound is equal to 26 cubic feet of vapor, $\frac{189}{26}$ = 7.3, so that 1 part gasoline-vapor to 7.3 parts air may be said to produce a perfect combustion of the mixture, so that less parts of air may leave a residuum of unconsumed vapor in the exhaust, while an excess of air may add to the fuel efficiency up to a possible limit of 1 part vapor to 10 parts air.

KEROSENE OIL

Kerosene oil is now taking a front rank among the fuels for explosive power, and crude petroleum is growing in favor as the most economical explosive-power fuel in use. Kerosene-oil motors are largely in the market and a number of concerns are building motors for crude-oil fuel. A "fuel-oil" (distillate) obtained from the residue after the kerosene has passed over from the still, and a grade cheaper than kerosene, is becoming available as an explosive-power fuel.

Kerosene has a variable specific gravity from 0.78 to 0.82, a

vapor flashing-point at 120° to 125° F., and the oil ignites when heated to about 135° F., and boils at about 400° F. Its vapor is five times heavier than air and requires about 190 cubic feet of air per pound for its complete combustion, or 76 cubic feet of air per cubic foot of its vapor. Its heat of combustion varies slightly from 22,000 B.T.U. per pound.

Fuel-oil (distillate) has an average specific gravity of 0.82 and weighs 7.3 pounds per gallon. Its vapor-flashing temperature is at 218° F., and temperature of distillation above 400° F., and it has a heat-unit value of about 18,000 per pound.

Crude petroleum varies considerably in the various parts of the United States in its chemical composition and specific gravity, with an average of 85, C. 14 H, 1.0 in 100 parts, and 0.88 to 0.90 sp. gr. Its heating value is about 20,500 B.T.U.

Crude petroleum and kerosene are available also by injection in a class of oil-engines of the Hornsby-Akroyd and Weiss type, in which the oil can be so atomized and vaporized as to make its entire volume available as an explosive combustible, in order that the accumulation of refuse shall be at a minimum. Crude oil is also used in the "Best" oil-vapor and other crude-oil engines by vaporizing the oil in chambers heated by the exhaust of the motor.

ACETYLENE GAS

FOR EXPLOSIVE ENGINES

Much interest has been lately shown and some experiments made in regard to the availability of carbide of calcium for generating acetylene gas as a fuel in the motive power of the horseless carriage and launches. Liquid acetylene has been also suggested as the acme of concentrated fuel for power.

The gas liquefies at −116° F. at atmospheric pressure, and at 68° F. at 597 pounds per square inch. Its liquid volume is about 62 cubic inches per pound.

The specific gravity of pure gaseous acetylene (C_2H_2) is 0.91 (air 1), and its percentage of carbon 0.923, and of hydrogen 0.077. Its great density as compared with other illuminating gases and the large percentage of carbon is probably the source of its wonderful light-giving power.

It is credited by hydrocarbon-heat values with 18,260 thermal units per pound of the gas (14½ cubic feet) and 1,259 thermal units per cubic foot. These figures vary in published statements.

One volume of the gas requires 2½ volumes of oxygen for perfect combustion, which is equivalent to 12½ volumes of air, provided that all the oxygen of the air can be utilized in the operation of a gas-engine; probably the best and most economical effect can be had from the proportion of 1 of acetylene to 14 or 15 of air. This proportion has been used in Italian motors with the best effect.

One pound of calcium carbide will yield 5¾ cubic feet of acetylene gas, and requires a little over a half pound of water to completely liberate the gas, so that where weight is a factor, as with carriages, tricycles, and bicycles, the output of gas will be but 3.83 cubic feet per pound of generating material. The large proportion of air required for perfect combustion makes a favorable compensation for the necessity for carrying water for generating the gas, as compared with gasoline, which yields 26 cubic feet of vapor per liquid pound with its best explosive effect of 9 volumes of air to 1 volume of vapor.

In liberating the gas from carbide in a closed vessel the pressure may rise to a dangerous point, depending upon the clearance space in the vessel, say from 300 to 800 pounds per square inch. In this manner a few accidents have occurred.

One pound of liquid acetylene, when evaporated at 64° F., will produce 14½ cubic feet of gas at atmospheric pressure, or a volume 400 times larger than that of the liquid. Its critical point of liquefaction is stated to be 98° F.; above this temperature it does not liquefy, but continues under the gaseous state at great pressures.

The heat-unit value of acetylene gas from its peculiar hydrocarbon elements, it will be seen, is far greater than that of gasoline-vapor per cubic foot, but experiments seem to have cast a doubt upon its theoretical value, and assigned a much less amount, or about 868 heat units per cubic foot.

As the comparative volume of explosive mixtures of gas or vapor and air is largely in favor of acetylene over gasoline, and as the weight of material for a given horse-power per hour also favors the use of acetylene, it will no doubt become a useful and

economical element of explosive power for vehicles and launches; always provided that the commercial production of carbide of calcium becomes available as a merchandise factor in cities and towns.

The explosive mixture of acetylene and air spontaneously fires at lower temperatures than illuminating-gas mixtures; it varies from 509° to 515° F., while illuminating-gas mixtures range from 750° to 800° F. Claims of a higher temperature have been made. It is of doubtful availability for high-compression motors.

In the use of liquid acetylene, the cost of liquefying the gas may be a bar to its ordinary use, but for special purposes there are possibilities that only future experiments and trials may develop into useful work from this unique element. In trials of acetylene for power in gas-engines, made in Paris, France, it was found that a much less volume of acetylene was required for equal work with illuminating gas and that it was a practical explosive fuel. The only change required was found to be a more perfect regulation of the valve movement, or a smaller valve to meet the smaller volume of acetylene. In these experiments the explosive mixture was approximately 10 parts air to 1 part acetylene; and using from 4 to 7 cubic feet of gas per horse-power per hour.

From another account of trials in France, it appears, as the result of experiments made by M. Ravel, that 6.35 cubic feet of acetylene gas generate 1 horse-power per hour, which is equivalent to a reduction of two-thirds as compared with petroleum. As to the explosiveness of mixtures of air and acetylene, it was found that 1.35 parts of this gas mixed with 1 part of air began to be explosive, the explosive force of such mixture rising rapidly as the dilution with air increases, attaining finally a maximum when there are 12 volumes of air with 1 volume of acetylene; then as the proportion of air is increased beyond this limit, the explosive force subsides, until at 20 to 1 it becomes entirely extinct. The flashing-point approximates 900° F., whereas in the case of most other gases used to generate power the requisite ignition temperature is about 1,100° F. The temperature of combustion is very much higher than that of the other gases with which it can be compared. The special characteristics of this gas, therefore, are great rapidity of the transmission of flame, low-ignition

temperature, high-combustion temperature, and extraordinary energy evolved in the explosion.

For the comparison of gasoline and acetylene, a series of tests were made with mixtures of air and vaporized gasoline in the ratio 4 to 1, which gave the greatest explosive pressure, 165 pounds, at initial pressure of 20 pounds. At the same initial pressure the 9 to 1 mixture of air and acetylene produced a pressure $\frac{273}{165}$ greater than that by the gasoline, so that the volume of acetylene to give the same pressure need only be $\frac{1}{2}\times\frac{165}{273}$ 0.304 of the gasoline.

Taking the theoretical indicator diagrams for the explosion of these two mixtures, the area of the acetylene diagram measured 4.91 square inches, and that of gasoline 1.79 square inches, giving a ratio of power nearly 3 to 1. Indicator diagrams show that the time rate of the actylene explosion is five times faster than that of the mixture of gasoline and air. As vaporized gasoline acts more slowly than acetylene, the practical test makes acetylene (mixture 9 to 1) 3.28 times more powerful than gasoline (ratio of 4 to 1), whereas theoretically it should be only 3 times as great.

The calorific value of the acetylene used was 1,350 thermal units and that of gasoline 700 heat units per cubic foot. A cubic foot of each of the above mixtures at initial atmospheric pressure would give 90 pounds and 43 pounds per square inch respectively. Allowed to expand adiabatically to 10 cubic feet, the calculated external work,

$$W=\frac{p_1v_1}{K-1}\left\{1-\left(\frac{v_1}{v_2}\right)^{K-1}\right\}, \text{ (where } K = 1.405),$$

would be for acetylene 22,403 foot-pounds, and for gasoline 12,132 foot-pounds. But only 0.0625 cubic foot of acetylene was used, while 0.20 cubic foot of gasoline-vapor was needed, or 3.2 times as much. With the given ratios of mixtures only 0.0312 cubic foot of acetylene is required to do the same work that 0.20 cubic foot of vaporized gasoline will do. Or comparing equal quantities of the two gases, acetylene has about 6.5 times the intrinsic energy of vaporized gasoline at the given ratios of air and gas.

Assuming an engine of total efficiency from fuel to useful work

of 15 per cent., and a consumption of 22 cubic feet of gasoline-vapor per horse-power per hour, the cost of 1-horse-power hour would be 1.3 cents, at 58 cents per 1,000 cubic feet of vaporized gasoline. The cost per horse-power per hour for acetylene in an engine of equal efficiency would be 2.6 cents, with acetylene $8 per 1,000 cubic feet, or 4 cents per pound. To do the same work with acetylene in place of vaporized gasoline, therefore, would be about twice as expensive. For this reason acetylene would only be of practical use to produce power where safety and light compact engines were required, as in automobiles and launches. In the event of a 50 per cent. reduction in the price of calcium carbide, however, it might probably come into more general use for gas-engines.

ALCOHOL AS A MOTIVE POWER

For some time past the French public has been studying a question interesting from the stand-point of the engineer, important from an economical point of view; the question of alcohol in its domestic and industrial applications. Among the latter the utilization of this combustible in explosive motors is the most interesting, and this is why the experiment has been tried of substituting for imported gasoline a national product resulting from French or colonial crops. One of the unquestioned advantages of alcohol over gasoline is that alcohol is a fixed product, whatever may be its use. The same alcohol for motive purposes can therefore be produced in any part of the globe, and its origin is revealed only by special aromas, which are of no consequence when it is used as a motive force.

If the consumption of alcohol-motors is compared with that of gasoline it is seen at once that the former consumes considerably more than the latter; and as the alcohol is the more costly of the two combustibles, the problem would seem *à priori* insoluble from an economic point of view.

Since denatured alcohol contains 4,172 heat units per pound, while gasoline contains 18,000, it has been found necessary to raise the calorific power of the former and at the same time lower its price, and so it has been mixed with high-grade gasoline of

70° gravity, which contains about 18,000 heat units per pound, and which can be produced under good conditions at a low net cost. Mixtures containing from 50 per cent. to 75 per cent. of alcohol have been used; but it is the 50 per cent. mixture, which has a calorific power of 11,086 heat units per pound, which seems to be the most advantageous at the present state of development. From the result of numerous trials made in France it has been found that the consumption of 50 per cent. carburetted alcohol is nearly the same as that of gasoline for a given power, and this notwithstanding the difference in the theoretical calorific powers of the two combustibles, from which it follows that the efficiency of the alcohol-motor is greater than that of the gasoline.

Some very exact experiments made by Prof. Musil at Berlin have shown the efficiency of various kinds of motors to be as follows: Motors run on city gas (according to the type), 18 to 31 per cent.; portable steam-motors, 13; kerosene-motors, 13; gasoline-motors, 16; alcohol-motors (mean figure), 23.8 per cent.

The high efficiency is evidently due to the great elasticity derived from the expansion of the water-vapor that is contained or produced by the alcohol at the moment of its combustion, this expansion tending to make the explosions in the cylinders less violent than when gasoline is used, and thus giving a longer life to the wearing parts of the motor. So much has this been found to be the case that in order to increase the beneficial action of the water-vapor the German Motor Construction Company, of Marienfeld, recommends a mixture containing 20 per cent. of water, and it has built motors to run on such a mixture that consume only .17 pound per horse-power hour. The fact must not be overlooked that in order to secure good efficiency with either pure or carburetted alcohol recourse must be had to specially constructed motors having the following characteristics: the stroke nearly double the bore, high compression, and a good spark.

Finally, the result of the latest experiments recently made in France on the "Economic" motor, which was specially constructed for use with alcohol, has been a lowering of the consumption to .124 pound per horse-power hour for medium-sized motors, employing a 50 per cent. mixture of carburetted alcohol. For stationary motors the problem is therefore solved.

When it has to do with automobiles the substitution of alcohol carburetted with gasoline is a matter of great interest, for it is evident from statistics that if a liquid containing 50 per cent. denatured alcohol could be used, a large industry would be induced.

As the results of late trials in France, the thermal efficiency of the following fuels of power are given: for gasoline, 14 to 18 per cent.; kerosene, 13 per cent.; gas, 18 to 31 per cent., and for alcohol, 24 to 28 per cent. The efficiency of gasolene and kerosene has been greatly improved in the United States in the last few years.

With the use of alcohol, an oxidizing effect has been noticed on valves and seats by the action of acetic acid derived from the occasional incomplete combustion of the alcohol and contained in the large amount of water-vapor from the hydrogen element in the alcohol.

This will, no doubt, be overcome by the use of non-corrosive valves and seats made from alloys that resist the action of acetic acid.

There is no doubt whatever that if the purchasers of automobiles required of the manufacturers carriages that would work equally well on 50 per cent. carburetted alcohol or gasoline the manufacturers would devise practical and simple apparatus, so that one combustible could be immediately substituted for the other, and that supply stations having carburetted alcohol would soon be established.

A little perseverance and attention is all that is necessary, therefore, to make the alcohol-motor prosper, as has already been done in Germany and France.

It is the consensus of opinion, and so far verified by practical work, that the regulation of the power of the explosive motor has its most economical working condition, first, in the variation of the quantity of fuel injected within certain limits for its highest explosive force with certain mixtures of air; and second, beyond this limit by the regulation of the quantity of the fuel and air mixture in their best proportions for highest effect.

It has been shown in other parts of this work that mixtures of good illuminating gas, one part to between five and six parts

air, give the highest constant volume pressure and the highest temperature by explosive combustion. Also that the time of combustion is quickest under the above proportion. But for all kinds of fuel there is a proportion of air mixture that gives the highest explosive pressure per unit of fuel quantity, and for economic work. This proportion should be retained by the governing mechanism for economic power.

There may be occasions when the over-riding of economical fuel conditions is done for imaginary conveniences in handling high-speed automobiles and launches, which are mostly through misguided judgment in regard to the best conditions of running, or from the ignorance of drivers in regard to the nature of the clouds of gasoline-vapor seen following the track of their vehicles or launches.

This condition is daily witnessed by the author from his residence, where the whirl of automobiles, at unlicensed speed, is in constant view, with a too frequent following of a cloud of gasoline-vapor that floats into the dwellings with its peculiar odor that signifies unburned vapor from excessive fuel feed; a needless waste that is a nuisance to the following vehicles and to roadside dwellers.

From the fact that it requires 7.3 parts of air to 1 part of gasoline-vapor for perfect combustion, it is obvious that the feeding of an excess of this fuel is not only a waste, but is also a loss of power, due to decrease of explosive pressure as the proportions are decreased in the charge mixture. The control by the fuel inlet alone should be confined to within the limits of 7.3 of air to 1 of vapor, and 12 of air to 1 of vapor; beyond these limits the control should include both air and fuel for economy and road-followers' comfort.

CHAPTER IX

CARBURETERS

THE use of the vapor of gasoline, naphtha, and petroleum oil for operating internal-combustion engines is increasing to a vast extent in all parts of the civilized world, and will be no doubt the cheapest medium for generating power so long as petroleum and its products are at the present low price. In gas-engine running, air saturated with the vapor of gasoline and naphtha is in general use, and when so used is produced by passing air through the liquid or over a surface largely extended by capillary attraction

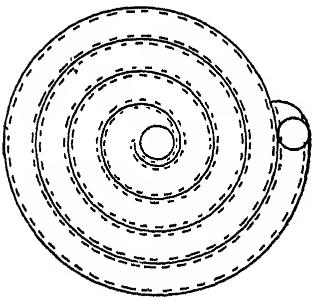


FIG. 25.—The circular carbureter, plan.

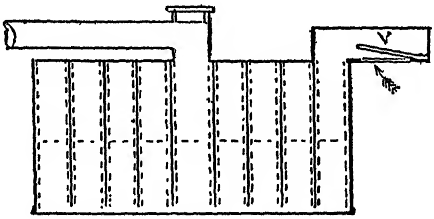


FIG. 26.—The circular carbureter, section.

of the fluid by fibrous surfaces dipping into the fluid, by vaporizing the fluid by means of the heat of the exhaust, and by injecting the fluid in small portions into the air-inlet chamber or under its valve, and directly into the clearance space of the cylinder.

In Figs. 25 and 26 are illustrated a form of carbureter, made by the writer many years since, for carbureting air and low-grade illuminating gas.

This carbureter may be made of heavy tin-plate. The spiral partition, made of tin-plate, is perforated with sufficient small holes at top and bottom to fasten strips of cotton or woollen flannel

on both sides of the spiral plate by stitching with coarse thread and needle. The spiral plate should extend so as to nearly touch the bottom of the tank; the bottom is to be soldered on last. The valve V, for the purpose of preventing the escape of the vapor when the carbureter is not in use, may be made as light as possible, of tin-plate or brass, and faced with soft leather wet with glycerine or a composition of glycerine and glue jelly, which always keeps soft and is not injured by the gasoline or its vapor. By this arrangement many square feet of surface may be obtained in a small space and perfect uniformity of saturation insured. As the enclosed walls of this form become very cold by long-continued use, an improvement was made by making each division wall with an outside air surface, so that there was a natural down-draught of air on the outside of the entire evaporating surface of the carbureter. In Figs. 27 and 28 are shown the plan and sections.

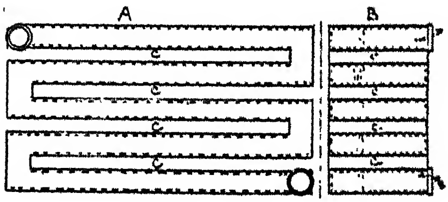


FIG. 27.—Plan and section of ventilating carbureter.

In this form the air spaces prevent excessive cold by a circulation of air downward against the cooling surface of the walls—the whole interior vertical walls being lined with cloth fastened to a wire frame made to fit each section and pushed into place before the ends of the sections are soldered on.

Very good carbureters have been made by a long cast-iron box with a cover bolted on with a packing of glue and glycerine jelly on felt or asbestos packing, in which a frame of wirework and cloth or yarn is made to give the desired evaporating surface.

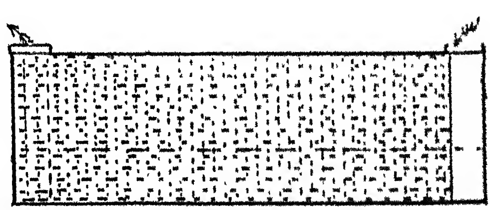


FIG. 28.—Section of ventilating carbureter.

For any carbureter of the forms here described, the depth should be limited to 8 inches, as the capillarity of the fibrous material is of little or no value at a greater height than 6 inches above

the fluid, which should not be charged above 3 inches in depth for best effect.

In Fig. 29 is represented the carbureter of the Gilbert & Barker Manufacturing Company, Springfield, Mass. It is made of wrought iron, has four divisions, in which perforated capillary partitions are set around each division or story of the carbureter, thus greatly enlarging the evaporating surface. The air enters the lower compartment, becomes saturated, and leaves the carbureter from the top. Provision is made for pumping out any residue that may require removal when the carbureter is placed underground.

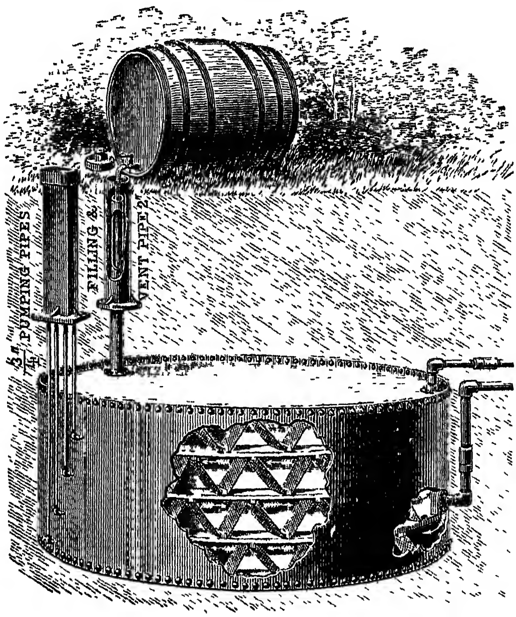


Fig. 29.—Gilbert & Barker carbureter.

Many other forms of carbureter have been tried, without, however, securing better results than with those here described.

Air saturated with gasoline-vapor has a heat value of about 200 heat units per cubic foot.

A claim has been made in France that by saturating part of the exhaust and by heating the gasoline, also by the exhaust, a concentrated vapor was produced which, used with the air, pro-

duced a power value of $\frac{3}{10}$ of a gallon of gasoline per horse-power per hour. There is no doubt that greater economies are in progress in the operation of gasoline and oil-engines; but the use of part of the products of combustion from the exhaust tends to lessen its value, if it has a value above its use as a part of the contents of the clearance space now in use in engines of the compression class.

The evaporation of gasoline of 0.74 specific gravity at a temperature of 60° F. varies somewhat from the form of its elementary constituents, and from the form of the evaporating surface; so that an average of 1,173 grains per square foot of saturated surface per hour in the open air may be assumed as the basis for carbureting surface.

When evaporated in a closed vessel, as a carbureter, the vapor may start at about 1,000 grains per square foot of surface per hour; but if the area of evaporating surface is so extended that little or no tension or pressure is produced by its evaporation, due to the draught upon it by the motor, and the temperature of the gasoline is kept near to 60° F., the evaporation may be relied on at about 800 grains per square foot per hour.

This gives a basis for computing the area of carburetted surface at any assumed consumption of gasoline per horse-power per hour. For example, gasoline weighing 6 pounds per gallon, with an assumed requirement of $\frac{1}{10}$ of a gallon per horse-power per hour, and an evaporation of 800 grains per hour per square foot, will require $\frac{\frac{6}{10}\times 7{,}000}{800}=5\frac{1}{4}$ square feet of evaporating surface in the carbureter per horse-power.

With our present experience there is no doubt in regard to the advantage, economy, and safety in the use of carbureters for gasoline, in which the air becomes thoroughly saturated with the gasoline-vapor before it meets the free air at the charging valve. Air saturated with gasoline-vapor is not explosive, and is considered in practice to be as safe in pipes and gas holders as any other gas used for illuminating purposes. It does not become explosive until further diluted to 5 parts of air to 1 part pure vapor. The mixture of air saturated with vapor of gasoline is largely in use in all parts of the United States for illuminating

purposes, conditioned as to safety and favorable insurance; therefore there is no bar to its use under the same conditions as an explosive element for power. Its safety will always be insured by an excess of evaporating surface in the carbureter.

So far as experience goes the sufficiency of the carbureter surface is a most important detail in its application for the fuel supply of a gasoline-engine, and its deficiency has been at the bottom of much trouble with the builders of these engines.

A point of great value in the economy of fuel has been brought out by German engineers, in trials as to the time of combustion in a cylinder and its relation to the perfection of the mixture of air and vapor. It was demonstrated experimentally that in the ordinary method of mixing a pure gas or vapor with air, at the instant of injection into the cylinder did not produce an instantaneous explosion, but from the first impulse the combustion continued throughout the stroke with a portion of unburned gas in the exhaust. This resulted, as observed, in a reduced initial pressure and consequent reduced efficiency by the indicator card. The continued combustion also increased the heat of the cylinder, as shown by the increase of temperature of a stated quantity of water for cooling a slow-combustion cylinder.

It was found experimentally that an injection of equal parts of gas and air into a cylinder required 6 seconds to become fully diffused, and that 1 part of gas to 6 parts of air required from 10 to 12 seconds for perfect diffusion. When, therefore, the time of a single revolution of a gas or gasoline-engine is considered, as compared with the time for charging and compression in a four-cycle cylinder, it will be seen that the mixture cannot become sufficiently intimate to permit the desired instantaneous explosion necessary for the highest fuel efficiency.

The tendency of efficiency in gas and gasoline-engine construction appears to be increasing in the line of more perfect mixture of the explosive fuel before injection into the cylinder; and to this we probably owe the possibilities now claimed of from 12 to 14 cubic feet of good illuminating gas, and $\frac{1}{10}$ of a gallon of gasoline per indicated horse-power per hour, and which in some cases has raised the pressure of explosion to 4 times the pressure of compression in four-cycle engines.

VAPOR-GAS FOR EXPLOSIVE MOTORS

Much of the risk and inconvenience of handling gasoline for motive power may be avoided by using the mixture of air and gasoline-vapor as a gas, and under the same conditions at the motor as with illuminating gas. Many power plants now utilize the vapor of gasoline generated at or in the immediate vicinity of the motor cylinder. This requires the presence of gasoline in quantity within the building, which largely increases the insurance risk, and is always a source of discussion and doubt with underwriters.

The vapor-gas as now extensively used for lighting dwellings and factories has been brought to such perfection in its generation and application to lighting purposes, as well also to many other applications of heat generated by Bunsen and other forms of gas-burners, that it may now be considered the most convenient form for a gas-generating system for isolated places, where an element is required for both lighting and power. The uncertainty of perfect diffusion of vapor and air with the present methods of producing the mixture of vapor and air near or within the cylinder cannot be considered the highest economy in the element of power production, in view of the assumed fact that commercial gasoline of an average of 0.75 gravity, weighing about 6¼ pounds per gallon, is claimed by the builders of the most economical motors to require but ⅛ gallon per actual horse-power per hour. This is equal to 0.78 of a pound, and the pound is credited with 18,000 heat units; or 14,040 heat units per horse-power per hour. This at 778 foot-pounds per heat unit is equal to 10,923,120 foot-pounds per horse-power per hour. The actual or brake horse-power per hour is 1,980,000 foot-pounds or 0.181 per cent. of the theoretical value of gasoline. With more perfect mixtures of vapor of gasoline and air the percentage in efficiency should be increased and a uniformity in the action of the motor obtained by a more perfect diffusion of the elements of combustion.

One of the means for automatically regulating the mixture of vapor and air is illustrated in the combined mixer and regulator of the Gilbert & Barker Mfg. Co., 82 John Street, New York, Fig. 30, and in Fig. 31, the mixer and meter air-pump placed within

a building. The carbureter, as shown in Fig. 29, p. 87, is placed in the ground or a vault outside of the building. The air is forced by the air meter-pump at a low pressure (1 to 1½ inches water pressure) to the carbureter on the outside of the building and returned through another pipe, loaded with the vapor of gasoline, to the regulator, where, by a differential gravity balance, a sup-

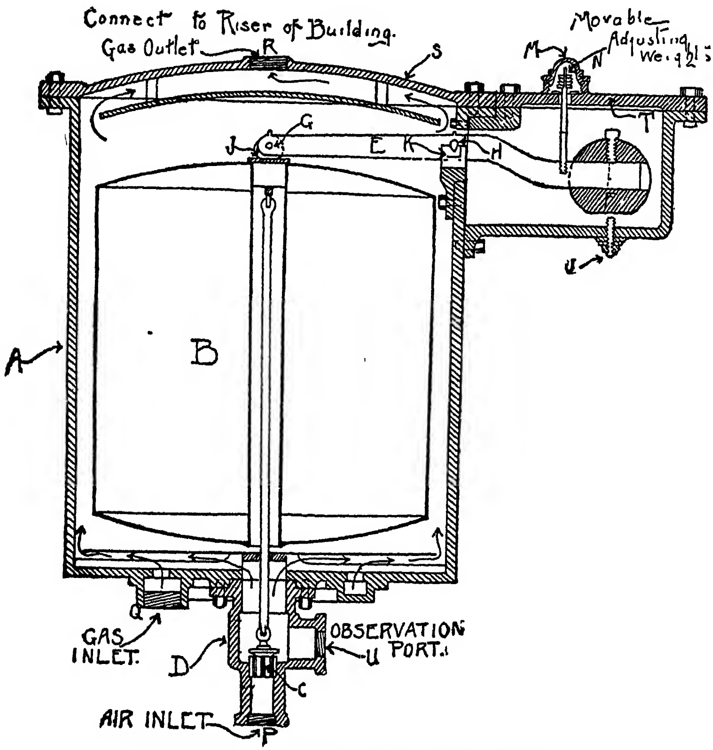


FIG. 30.—The differential gravity regulator.

plementary valve is opened by which a direct current of air enters from the pressure-pipe of the air meter-pump and dilutes the direct vapor charge from the carbureter to a uniform mixture, thus producing a constant flow of gas of a gravity for the best effect in lighting, and also, when further diluted at the inlet-valve, for the best explosive effect in a motor.

The pure vapor of gasoline is of a gravity of 2.8 (air 1) and the air-gas vapor as it comes from the carbureter may be of vary-

ing gravities from 2.5 to 1.5 (air 1), and it is the difference in the gravity of air and the heavier vapor of gasoline and air as it comes from the carbureter that operates the diluting mechanism of the apparatus to produce a mixture of uniform quality. For this purpose, the float B is a sealed metal can, containing air which with its weight and the air inlet-valve C is exactly balanced by an adjustable counterpoise F and enclosed within a cast-iron

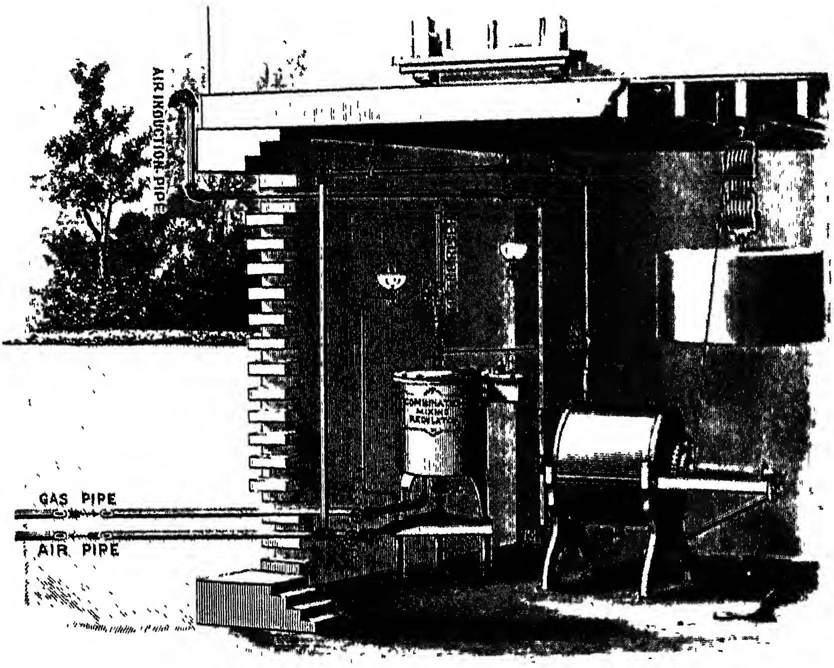


FIG. 31.—The air pump and regulator.

case. The vapor-gas enters at the bottom through an annular inlet Q from the carbureter and fills the case with a vapor mixture slightly heavier than the balanced can of air, which is thus caused to rise and open the direct air inlet-valve C, admitting air at a slightly increased pressure, due to differential friction, as between the short-air connection with air-pump and the long-pipe connection to the carbureter and back to the regulator.

By the delicate adjustment of the counterpoise weights at M the exact conditions for a uniform gravity gas supply may be

obtained for lighting. This is assumed to be also the most economical for combustion in an explosive motor; it then requiring only the regulating admixture of air at the inlet-valve of the motor cylinder for adjusting the force of explosion and for regulating the speed of the motor.

Fig. 31 shows the arrangement of setting the air-pump and regulator with the short-circuit of the air-pipe to give a preponderance to the air pressure at the regulating valve C (Fig. 30). For motor service a gas equalizing bag should be used as with other kinds of gas supply.

A strong feature of this carbureter, as illustrated at Fig. 29, is the large evaporating surface, it being in fact a compound generator consisting of a number of independent and perfect evaporators, one placed over the other. The effect of cold by evaporation commences at the bottom pan, and the saturation of the air is completed in the next pan, and so on successively, so that deterioration does not commence until the last or top pan is partially exhausted.

The air-pump is of the wet-gas meter type with the motion inverted and propelled by a weight as shown in Fig. 31, or by a small overshot water-wheel operated by a jet from any source of water pressure.

ATOMIZING CARBURETERS AND VAPORIZERS

In Fig. 32 is illustrated a novel atomizer and vaporizer for a marine engine. The rising vapor-pipe is shortened in the cut for the convenience of illustration.

The gasoline tank is placed in the bow of the boat and the atomizer at the base of the engine. The gasoline flows to the chamber F by gravity and is stopped by the deep-seated conical valve E. The cage of the air inlet-valve D is screwed into the metal box at B and is adjustable so as to bring the push-centre of the valve D to the proper distance for operating the gasoline inlet-valve E. The lift of the air-valve D is also adjustable in its lift by the lock-nuts at I on the spindle C, which is guided by a cross-bar near the top of the cage. The main air inlet is at H with a diffusion inlet at G regulated by a plug-cock. The gaso-

line is thoroughly atomized by the action of the two valves E and D, and meeting the fresh air through G is vaporized in its passage through the pipe and inlet-valve chamber.

In Fig. 33 is illustrated a heat vaporizer used on the "Capitaine" motor in which the inlet nozzle V is ribbed on the outside and is enclosed in a chamber through which the exhaust passes.

Gasoline and air are drawn into the nozzle regulated by the small valve, and additional air for the explosive mixture is drawn

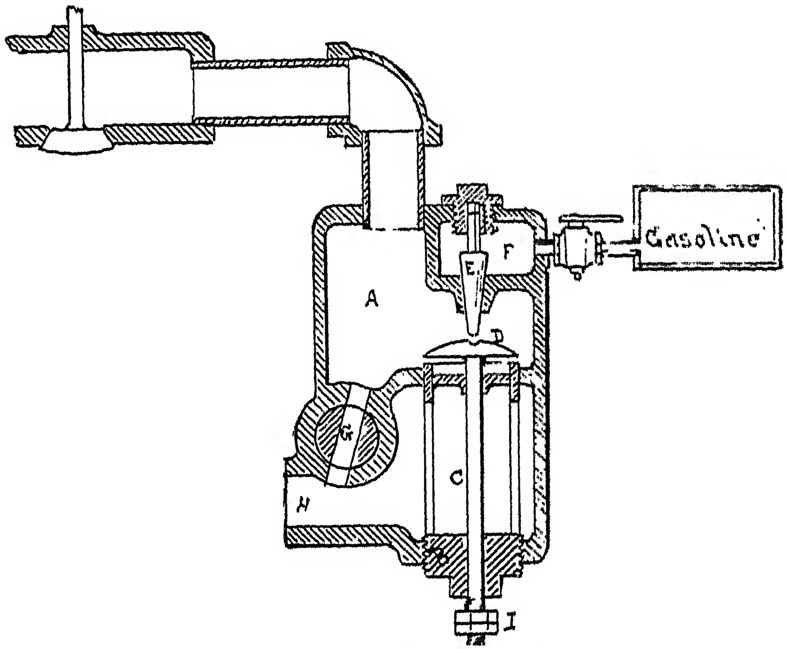


FIG. 32.—Gasoline atomizer and vaporizer.

in by the piston through the large valve. By this arrangement the gasoline is broken up and thrown against the hot walls of the nozzle by the air drawn through the small air inlet.

The atomizing vaporizer (Fig. 34) is conveniently placed on the side of a cylinder with the exhaust-valve G spindle in line with the exhaust push-rod.

The gasoline is injected through the small valve C, opened by the lift of the air-valve D. The inlet-valve E makes a closure

of the vaporizing chamber during the compression and exhaust-stroke of the piston.

The constant-level feed atomizer (Fig. 35) is of French origin and used on the "Abeille" automobile motor. It regulates its feed from a higher-level reservoir or tank, by means of a float B in the receiver A, which, by its floating position, opens a small conical valve on the lower end of the spindle C through the operation of the lever D. The spindle C being a counterpoise weight to close the inlet-valve when the float B exceeds the proper height.

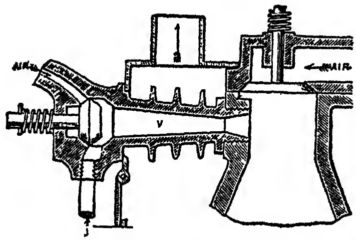


FIG. 33.—Heat vaporizer.

The level of the gasoline in the receiver is adjusted to stand just below the top of the jet nozzle at E.

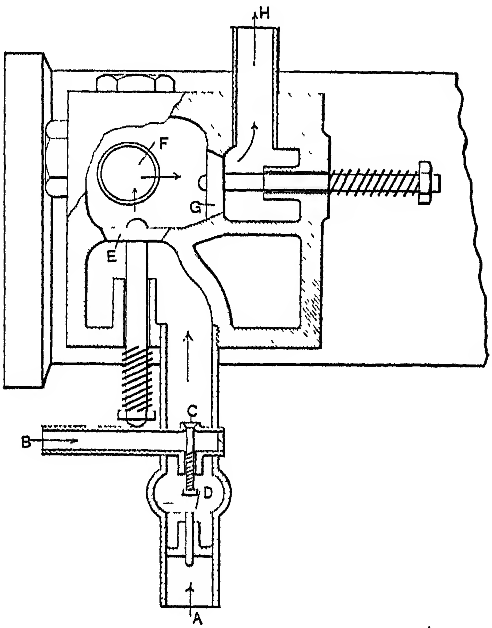


FIG. 34.—Atomizing vaporizer.

An inlet for air to meet the gasoline jet J at the neck of the double cone H is shown in the circular opening in the oval flange. The suction of the piston during the charging stroke jets the gasoline against the perforated cone with the annular jet of air from below, where it is met by the diluting air from the holes in the cone. The cap L has holes corresponding with the holes on the inner section for adjusting the area of the diluting air inlet by rotation on its screw thread. The jet nozzle can be quickly removed, cleaned, or adjusted by removing the plug F.

A vaporizer having some excellent features for perfecting the vapor and air mixture before it enters the cylinder is detailed in Fig. 36 and patented by Walter Hay, New Haven, Conn.

The gasoline enters the small annular chamber *aa* through the pipe *d*. Several small holes open from the annular chamber upon the central line of the valve seat of the inlet air-valve E, some of which have screw needle-valves for regulating the flow of gasoline. The inrush of air when the valve opens by the draft of the piston atomizes the inflowing gasoline and precipitates the atoms upon the deep wings of a fan *h* hung upon the central spindle *j*. The fan is set in motion by the inrush of air, and throwing the excess of gasoline against the hot walls of the annular exhaust-chamber *a'f*, produces a perfect mixture of vapor and air before passing through the second inlet-valve A. The exhaust in passing around the annular chamber also imparts heat to the annular gasoline chamber *aa'* and makes its final exit through the slotted apertures in the outer casing, as at *g*, or may pass into an exhaust-pipe.

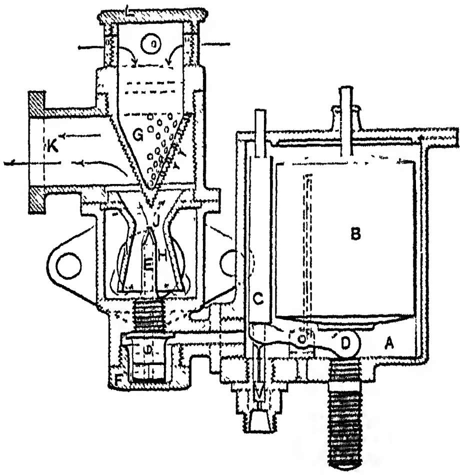


Fig. 35.—Constant-level atomizer.

We illustrate in Figs. 37 and 38 two forms of atomizers or mixing valves which have been designed for use on gasoline-engines. They take the place of carburetors, and, for certain purposes, users have found them efficient and reliable. The construction of these valves is very simple. They have few parts, and there is no liability of their proving troublesome after having been used a short while.

Referring to the sectional views it will be seen that the valve disk E is held against its seat by a light spring M. The seat of this valve is wide, and the port opening slightly smaller in diam-

eter than the pipe connections. The body of the valve L below the valve disk is of full area. At the side of the valve body is a gasoline inlet O tapped for $\frac{1}{4}$-inch pipe thread. From the side gasoline inlet O a passageway of ample area leads around and through the valve body and is in communication with the main valve seat. The opening of this passageway K into the valve seat is controlled by a small needle-valve F, which has an indicator arm G.

The valve stem F has a stuffing-box H so as to enable it to be well packed to prevent leakage of gasoline.

In this construction no gasoline is spilled, nor will it accumulate in the valve body; any excessive amount will be drawn into the vaporizing space between this and the inlet-valve. The sizes are designated by the pipe size of the screw and are rated for cylinder sizes as follows:

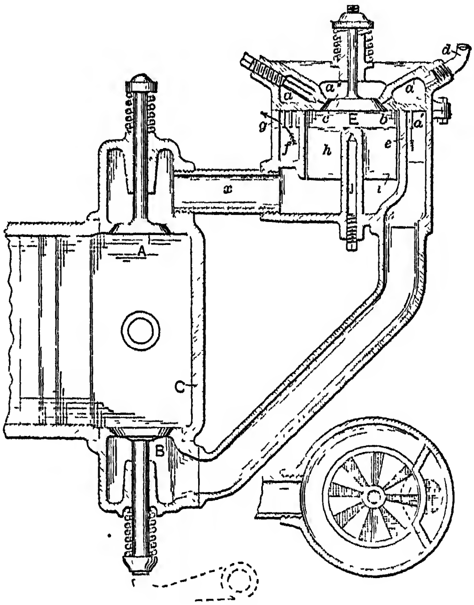


Fig. 36.—The "Hay" vaporizer.

Diameter of Cylinder, inches...	2	3½	4½	5½	7	8	10	12	14
Size Pipe Connection on Generator Valve, inches............	½	¾	1	1¼	1½	2	2½	2½	3

The above proportions are based on a piston travel of not more than 600 feet per minute. For higher speeds than this the generator valve should be the next size larger than shown above.

The valves are made by the Lunkenheimer Company, Cincinnati, O.

The plan and section of a noiseless automatic carbureter is

shown in Fig. 39. It is well suited for charging multiple-cylinder motors and is very uniform in its supply. The left-hand section of the cut shows the plan of the float tank, valve, and the wire gauze in the air-pipe, of which there are sufficient in number, say nine, to give a large wire surface for fully evaporating any charge of gasoline for the motor for which the size of carbureter is adapted.

Referring to section of carbureter as cut on a line AB, with position of adjusting screw shown at *a*. The level of gasoline

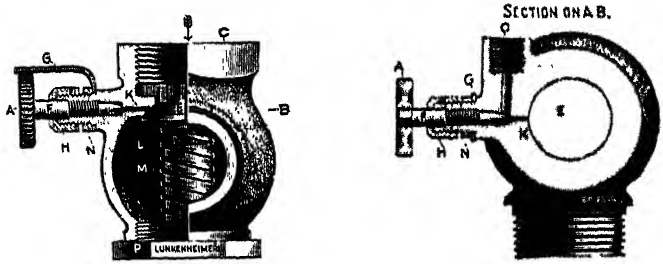


FIG. 37.—Angle atomizer.

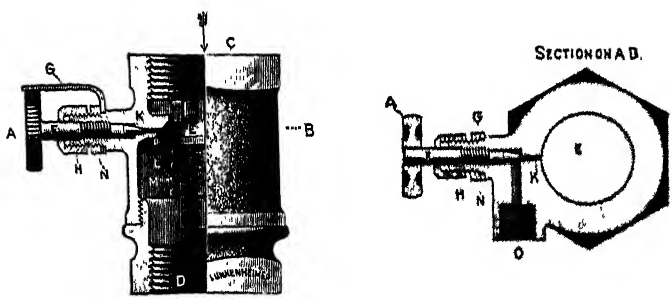


FIG. 38.—Vertical atomizer.

being lifted automatically by the suction of the motor, the supply is shown below point of adjusting screw, the gasoline being regulated by the needle-point on screw which forms the spraying nozzle and the constant level being maintained at all times by the ball-valve *v*, which has a capacity much greater than outlet at needle-point, so it is easy to see that it would be impossible to lower the level of gasoline. And the float acting as it does on the lever *l*, and *l* resting as it does squarely on the centre of the ball and the ball fitted in a perfect seat, the float being hinged to lever, it will

be seen that any vibration that would cause the float to shake within the cup will not disturb the ball, which will maintain a constant level through any kind of vibration, making it perfectly adapted to engines and motors for traction or marine purposes as

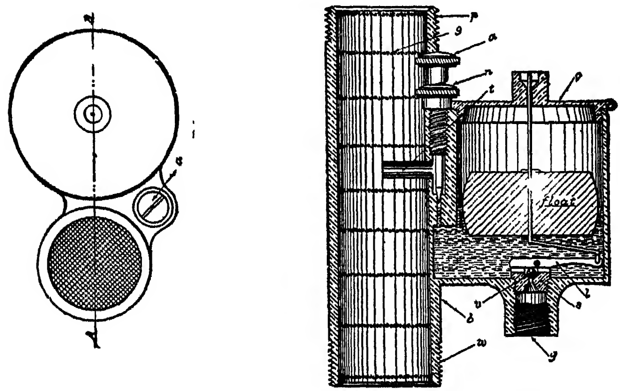


FIG 39.—Kingston carbureter.

well as stationary. This carbureter may be used with a throttling governor if desired.

In Figs. 40 and 41 we illustrate a later design of the Kingston carbureter of which Fig. 40 is an outside view and Fig. 41 a section showing the detailed parts.

In describing the principle and method of throttle control in this carbureter we will refer to the vertical cross section showing the entire workings of this carbureter: J represents the float chamber; F, the float; *v* the bell-metal ball-valve and valve-stem to which the float is rigidly connected; G the fuel connection; T a trap at bottom of float chamber to catch and hold any dirt or water that may find its way to float chamber; P is a ⅛-inch pipe plug which may be

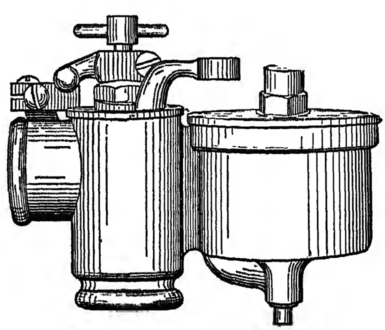


FIG. 40.—New Kingston carbureter.

taken out for draining and cleaning the trap, for convenience this plug may be taken out and a pet-cock screwed in its place;

H represents the air chamber; *a* the fuel needle-point valve; D the air-regulating valve; *d* a lug cast on air-valve, used as an adjustable stop, being provided with screw and clamp to hold screw firmly after adjustment is made; *e* is a lug on main casting forming a stop for *d*; this screw adjustment at *d* is used for adjusting throttle for low speed; *s* is a clamp having a fork at one end for making a loose connection with *d*, the other end forming a clamp with screw tension for locking same to *a* after the fuel adjustment is made; L is a lever for operating *a* and D together forming the throttle; *t* the fuel-spraying nozzle in tube projecting from cavity shown around needle-point of *a*, this nozzle is placed in apex of *v*-shaped orifice leading to the engine, also connection for intake pipe to motor; I is the air inlet to carbureter; M, M are baffle-plates which are thin semi-disks or bridges and closing one-half the opening in each case from opposite sides, and doing service as baffle-plates, keeping the mixture from being forced back out I by reaction on back-lash of motor valves, also as a silencer as they muffle the inrush of air; V represents a conduit leading from float chamber and terminating at *t* at apex of *v*-shaped orifice leading to the motor; the flow of fuel through V being controlled by needle-valve *a*.

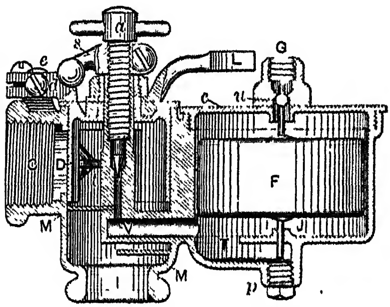


FIG. 41.—Section Kingston carbureter.

These carbureters are made by Byrne Kingston & Co., Kokomo, Ind.

We illustrate in Fig. 42 and Section Fig. 43, a vaporizer of the constant-level type with a regulating device in which the index to the gasoline feed is adjusted by a sector and worm screw which cannot be displaced by jar or vibration.

It will be seen that the device is very compact, practically all of it being contained in a space but little larger in diameter than the ordinary inlet-pipe. Gasoline enters from the supply through the pipe *m*, filling the reservoir *d* and overflowing through the passage *g* to the pipe *l*. Air enters through the openings in the cap

e, which serves to throttle the air supply. Passing around the chamber *d* it produces a draft which draws fuel from the reservoir through the nipple *c* and the plug-valve *i* which is counterbored at *j*. Passing onward, the mixture of gasoline and air leaves the casing *a* through the pipe *b*, which is threaded so that it may be connected to the inlet of the engine. The vent *h* keeps the pressure constant within the reservoir and the gasoline may be drained through the cock *k*.

Those who have had experience with gasoline vaporizers will at once recognize the good features of this device, which are the location of the gasoline nozzle in the centre of the air passage, the location of the fuel-valve close to the opening of the nozzle

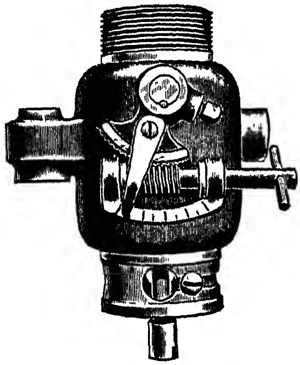


Fig. 42.—Aldrich vaporizer.

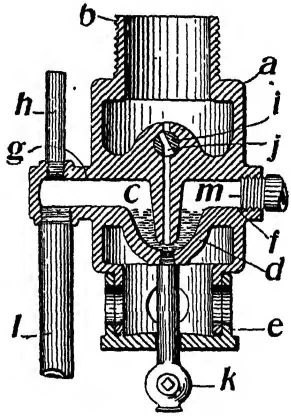


Fig. 43.—Section.

into the air passage and the general compactness of the entire vaporizer. It is manufactured by R. & W. T. Aldrich, Millville, Mass.

THE CLUADEL OIL-CARBURETER

A French design by M. Cluadel for carbureting air with kerosene or the heavier oils by the heat of the exhaust.

The carbureter is composed of a double heating chamber *u*, in the centre of which is placed the retort *m*. In the annular space included between the retort and the outer walls of the heating chamber, the exhaust from the motor circulates, entering by the

pipe k and escaping by the pipe l. The position of the retort m is assymmetric with regard to the centre of the heating chamber, in proportion to the supply and exhaust-pipes, k and e; so that the amount of heat imparted to the retort may be regulated by the movement of the valve s in Fig. 45.

With the valve in the position shown, the flow of heated gases from the exhaust follows the course of the arrow 2, Fig. 46, being in contact with only a small portion of the circumference of the retort, and imparting but little heat. With the valve in the position shown by the dotted lines, the current of gas, following the direction of arrow 1, almost completely surrounds the retort.

The difference between the two passages is further increased by a very thin wall on the right of arrow 2, which may be in the form

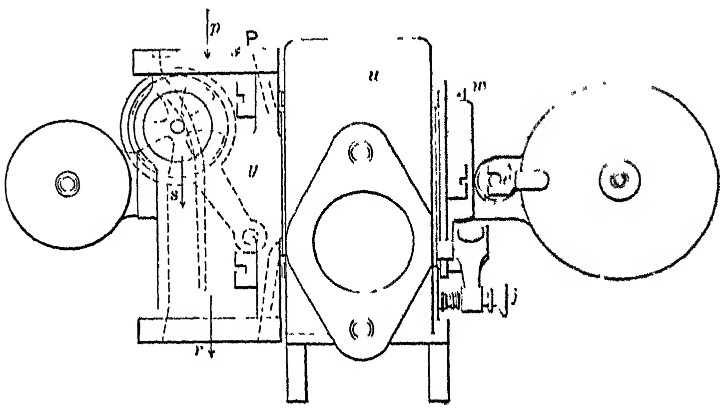


FIG. 44.—Plan and top view of carbureter.
Dotted lines show auxiliary air intake.

of a screen or damper permitting an ingress of outside air; while the wall on the left of arrow 1 is a part of the casting of considerable thickness, thus retarding the radiation. The air-valve is operated by the lever and spring stop, while the cam lever T (Fig. 46) regulates and locks the cooling damper. By the proper adjustment of these two valves, and the diversion of the exhaust, the retort may be maintained at any desired temperature up to the maximum limit of the exhaust.

The retort is made of drawn tubing, which may be formed with an internal web n, increasing the heating surface and breaking the

flow of the combustible contents. The retort is connected with the mixing chamber *y* by the tubes *o, o, o,* of such size and form as to act in connection with the web *n* to break up the various elements

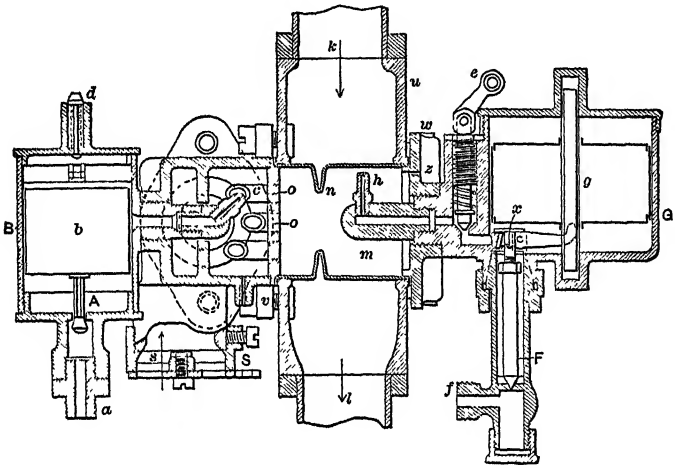


FIG. 45.—Vertical section of Cluadel carbureter for heavy oils.

A, Regulator for gasoline supply. B, gasoline reservoir. F, Stop-valve for oil supply. G, Oil reservoir. P, Damper of main air supply. S, Damper of auxiliary air supply. T, Locking lever of air-damper of exhaust. *a*, Gasoline supply. *b*, Gasoline float. *c*, Gasoline feed-nipple. *d*, Button for lowering float. *e*, Independent oil-supply valve. *f*, Oil-supply pipe. *g*, Oil float. *h*, Oil feed-nipple. *j*, Stop and lever of exhaust-pipe valve. *k*, Supply pipe from exhaust to carbureter. *l*, Discharge pipe of exhaust. *m*, Retort. *n*, Rib of retort. *o, o o*, Mixing pipes from retort. *p*, Main air supply. *r*, Pipe from carbureter to motor *s*, Auxiliary air supply. *u*, Heating chamber for retort *v*, Drain *x*, Adjusting-screw of oil-supply valve. *y*, Mixing chamber. *z*, Air-duct to retort.

within the retort and to provide the throttling which is essential to automatic regulation.

The mixing chamber is provided with three openings; one for the main air supply, *p;* one for an auxiliary air supply, *s;* and one, *r*, for the passage of the mixture to the motor. An internal diaphragm directs the course of the air admitted by *p* and *s*, and regulates the suction according to the speed and other conditions. The opening *s* is fitted with a damper by which the auxiliary supply may be regulated according to the kind of oil used.

Attached to the mixing chamber is the float chamber B of the ordinary gasoline carbureter, with the float *b*, regulating the level of the gasoline which enters by the tube *a*, and which is discharged into the air of the mixing chamber by the nipple *c*, on first starting the motor.

The regulation of the heavy oil supply is through the float chamber G, and float g, the oil entering at f, under the control of the point F. The float g operates a lever, which acts on the upper end of the pointed rod F, the exact adjustment being made through the screw x and its nut. Between the discharge-nipple h, within the retort, and the float chamber G is a spring valve operated by the lever e, by which the passage of the oil may be controlled.

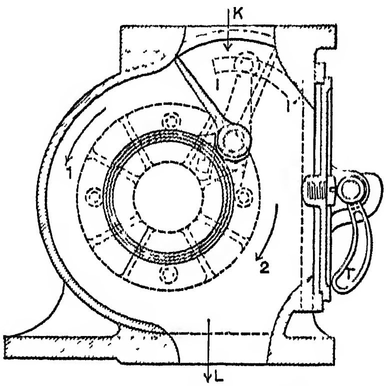


FIG. 46.—Transverse vertical section through retort and exhaust-pipe.

A very important detail of the retort is the plate w, which connects it with the oil-float chamber, and which is pierced, as shown by a small opening z, which admits the necessary amount of free air in proximity to the nipple h.

METHODS OF STARTING

In practical operation, the motor may be started by means of the auxiliary gasoline-carbureter on the left, with a small reservoir for fuel, and when well under way and with the exhaust going, the gasoline may be shut off and the kerosene turned on. The motor may, however, be started directly on the oil, provided a torch is first used to heat the retort until a flow is secured from the exhaust.

The oil supply in the reservoir G is maintained at a constant level by means of the float g and its lever acting on the valve F; the rate of feed through the nipple h is regulated by the amount of pressure within the retort m, which is in turn dependent upon the flow of the gases through the contracted opening of the rib n and the indirect passages of the mixing tubes o, o, o, which serve to alter the effect of the motor's aspiration and to make it prolonged and regular instead of intermittent. At the lower speeds there is very little resistance to the flow from the retort to the mixing chamber; but as the speed increases and the aspirations of the

motor become more powerful, the effect is to throttle the gas in its way through the indirect passages. The result of this apparently contradictory phenomenon is an automatic regulation which is practically perfect. Once set for a given quality of oil, the supplementary air supply *s*, *s*, may be left without further attention; the air duct *z* of the retort remains unchanged; and the position of the regulating valve *i* in the exhaust-pipe as set by the lever and stop *g* is also unchanged. It has been found in practice that the exhaust supply-pipe *k* should be placed as close as possible to the heads of the cylinders.

In Fig. 47 is illustrated an atomizing vaporizer of the Generator Valve Co., New York.

It has an addition to the ordinary atomizing devices, a throttle-valve with spindle and handle L, to regulate the charge, and ready to connect with any two-cycle motor by the screw at I.

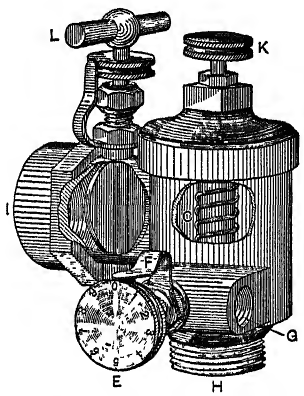


FIG. 47.—Atomizing vaporizer.

The air inlet is at H, gasoline inlet at G. The needle-valve opens on the air-valve seat and carries a milled index-head E, held as set by the spring pointer F. The air inlet-valve is closed lightly by the spring C, and its lift adjusted by the milled head-screw K. The throttle-valve is held in any set position by pressure of a spring on the milled disk on its spindle.

CHAPTER X

CYLINDER CAPACITY OF GAS AND GASOLINE-ENGINES

The cylinder volume of gas and gasoline-engines seems to be as variable with the different builders as it is with steam-engines in its relation to the indicated power.

The proportion of diameter to stroke varies from equal measures up to 38 per cent. greater stroke than the measure of the cylinder diameter. The extreme volumes of cylinder capacity (measured by the stroke) varies from 28 to 56 cubic inches for a 1 horse-power engine and from 48 to 98 cubic inches for a 2 horse-power engine; for a 3 horse-power engine from 77 to 142 cubic inches, while for a 6 horse-power engine it ranges from 182 to 385 cubic inches. This disparity in sizes for equal indicated power may be caused by the different kinds of gas and its air mixtures under which the trials for indicated power may have been made, or it may be partly due to relative clearance and facility for exploding the charge at some fixed time.

It may be readily seen from inspection of the heat value of different kinds of gas—varying as they do from about 950 heat units per cubic foot for the highest illuminating gas to from 185 to 66 heat units in the different qualities of producer-gas that large variations in effective power will result from a given-sized cylinder. It will also be plainly seen that with the extreme dilution of producer-gas with the neutral elements that produce no heat effect, that no combination with air that also contains 80 per cent. of non-combustible element can produce even a modicum of power in the same-sized cylinder as is used for a high-power gas.

In view of this it seems necessary to build explosive engines with cylinder capacities due to the heat-unit power of the combustible intended to be used, as well as to the method of its application.

In the following tables are given the indicated and actual

power, revolutions, and size of cylinder and stroke of various styles of gas-engines for comparison:

TABLE XIII.

The Nash.				The Sintz.			
Actual Horse-Power.	Revolutions per Minute.	Diameter of Cylinder. Inch.	Stroke. Inch.	Horse-Power.	Revolutions per Minute.	Diameter of Cylinder. Inch	Stroke. Inch.
⅓	350	3	4	1	425	3½	3½
½	350	3½	4	2	400	4	4
1	325	4	4½	3	375	4¾	5
2	300	5	5	4	350	5	6
3	300	5½	6½	6	300	5¾	6
4	300	6	7	8	270	6½	7
5	280	6½	7½	10	250	8	8
				15	225	9	9

TABLE XIV.

Star.				Dimension Table, Page 110.			
Actual Horse-Power.	Revolutions per Minute.	Diameter of Cylinder. Inch.	Stroke. Inch	Horse-Power.	Revolutions per Minute.	Diameter of Cylinder. Inch	Stroke. Inch.
2	250	4½	6	2	350	4½	5½
3	240	5	6	3	350	5	6¼
4	220	5½	10	4¾	325	6	7½
6	220	6½	12	7	320	7	8¾
8	180	7	13	10	300	8	10
10	180	8	14	13	275	9	11¼
				17	250	10	12½

TABLE XV.—RATING OF SOME ENGLISH ENGINES.

Indicated Horse-Power.	Revolutions.	Diameter. Inches	Stroke. Inches.	Name.
9	164	6	16	Crossley.
9	164	8	16	"
14	200	7	15	"
16	160	11½	20	Burt's Otto.
18	180	9¼	16	" "
19	160	9½	18	Crossley.
20	184	9¾	17	Stockport.
20	164	12	18	Wells.
24	180	10	18	Barker's Otto.
30	170	12	20	" "
33	210	17	21¼	Crossley.
40	160	18	24	Tangye.

The apparent discrepancies in the above table of cylinder capacities, as to their size when compared with their indicated power, are not really so great as may be noticed at first inspection; for the mean pressure varies very much with the various fuels, as well also from the relative variation of the proportion between the volume of the combustion chamber and the volume swept by the piston. The difference in speed between the various engines noted also complicates the direct comparison for cylinder capacities.

The whole subject of size and weight of explosive engines for stated powers appears to be still in the experimental stage, which by continued experiment and experience may be brought into an approximate uniformity in practice for specified values of fuel and speed.

CYLINDER DIAMETER, STROKE, AND MOTOR PARTS

The practice in cylinder proportions in the United States appears to vary considerably among engine builders, from equal diameter and stroke to from $1\frac{1}{4}$ to $1\frac{1}{2}$ their diameter for length of stroke, while in Europe the smaller-sized engines have strokes of more than twice the diameter, grading to $1\frac{1}{2}$ times in the larger engines.

Like the steam-engine cylinder proportions, there seems to be no settled opinion as to the best ratio, except that high speed indicates short stroke. The longer stroke European engines are quoted as low speed and run at from one-half to two-thirds the speed of most American engines of the same caliber.

In the following table of gas and gasoline-engine dimensions we have figured the speed at about the maximum rate and have endeavored to show about the average practice with builders of four-cycle engines in the United States for ordinary power use.

The table has been computed for convenient measurement for amateur use and may not meet the exact and decimal values for expert designers.

In assigning these values a consideration of 60 pounds M.E.P., with a clearance of from 30 to 35 per cent. of the piston stroke, has been made for the combustion chamber.

The tabulated horse-power has been computed on the basis

of the M.E.P. of 60 pounds per square inch with an adiabatic compression of $\frac{39}{100}$ of the total volume and a mean back-pressure from the compression stroke of 26 pounds per square inch, which is deducted from the mean of the explosive-pressure stroke of 89 pounds per square inch; which being 63 pounds, from which a deduction of 3 pounds is made for losses from leakage, leaves a net mean pressure of 60 pounds.

Then the cylinder area × mean explosive-pressure − mean compression pressure × impulse stroke travel in feet per minute and product divided by 33,000 = indicated horse-power.

$$\frac{A \times \text{M.E.P.} \times S}{33{,}000} = \text{I.H.P.}$$

To obtain the value of S, multiply the stroke in feet or decimals of a foot by one-half the number of revolutions per minute, which is the impulse travel of the piston per minute. If misfires are made they should be deducted from the half number of revolutions in practice.

As an example of an 8 × 10 four-cycle engine at 300 revolutions per minute, we have area of cylinder 50.26 square inches and $S = \frac{10}{12} \times \frac{300}{2} = 125$ feet piston travel per minute. Then $\frac{50.26 \times 60 \times 125}{33{,}000} = 11.41$ I.H.P., which we have rated as 10 actual horse-power in the table. In the smaller engines the difference between indicated and actual horse-power increases as the size diminishes.

The thicknesses of cylinder wall, water-jacket, and water space have been assigned with due regard for overcharged explosions and the possibilities in core-making for the water space; they are often made thicker than given in the table.

The length of the connecting rod from centre to centre is made from medium practice, or about $2\frac{1}{4}$ times the stroke with the piston-pin at the centre of the piston.

The figured dimensions of piston-pins of the same bearing length as the crank-pin, as also the crank-pins and shaft, are derived approximately from formulas which we find variable with

different writers, as well as variable in size by different builders of explosive motors. The dimensions in the table are a medium suitable to a clearance ratio of 3 to 3.5.

APPROXIMATE DIMENSIONS OF FOUR-CYCLE MOTOR PARTS.

For M.E P. 60 lbs. Clearance, 30 to 33 per cent. Compression, 50 to 60 lbs. Explosive Pressure, 160 to 200 lbs.

TABLE XVI.

Actual Horse-Power.	Revolutions.	Cylinder Diameter.	Stroke.	Clearance. Inches	Thickness Cylinder Wall.	Water Space.	Water Shell.	Length Connecting Rod.	Size Piston-Pin.	Size Crank-Pin.	Width Crank-Pin.	Size Main Journal.	Length Main Journal.	Diameter Fly-Wheels.	Weight Fly-Wheels.	Size Inlet-Valve.	Size Exhaust-Valve.
		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins	Ins.	Ins.	Ins.	Lbs.	Ins.	Ins.
¼....	500	2	3½	1	[illegible]	3/16 x ¾	Ribs	8	[illegible]	[illegible]	[illegible]	[illegible]	1	13	66	[illegible]	[illegible]
½ ...	450	2½	4	1⅛	[illegible]	3/16 x 1 Ribs	Ribs or	9	[illegible]	[illegible]	[illegible]	[illegible]	1¼	15	133	[illegible]	[illegible]
¾....	425	3	4¼	1¼	[illegible]	[illegible]	[illegible]	9½	7/16	1	1	[illegible]	1½	17	200	[illegible]	⅞
1.....	400	3½	4½	1⅜	[illegible]	[illegible]	[illegible]	10¼	[illegible]	1¼	1¼	1	2	18	270	⅝	1
1½.. .	350	4	5	1⅝	[illegible]	[illegible]	[illegible]	11¼	[illegible]	1⅜	1⅜	1¼	2¼	20	475	1	1⅛
2.. ..	350	4½	5¼	1⅞	[illegible]	[illegible]	[illegible]	12	[illegible]	1½	1⅝	1¼	2½	23	525	1¼	1¼
3	350	5	6¼	2⅛	[illegible]	[illegible]	[illegible]	14¼	[illegible]	1⅝	2	1⅜	3	26	575	1¼	1⅜
4¾ ...	325	6	7½	2⅜	[illegible]	[illegible]	[illegible]	17	1⅛	2¼	2¼	1¾	3½	32	800	1⅜	1½
7 . ..	320	7	8¾	2¾	[illegible]	[illegible]	[illegible]	20	1¼	2½	2¼	2¼	4½	38	900	1½	2
10 . ..	300	8	10	3¼	[illegible]	1	[illegible]	22½	1⅜	3	3¼	2⅝	5¼	44	1130	2	2¼
13	275	9	11¼	4	[illegible]	1	[illegible]	25½	1½	3¼	3½	2⅞	5¼	50	1500	2¼	2½
17	250	10	12½	4⅜	[illegible]	1⅛	[illegible]	28¼	1¾	3½	4	3¼	6¼	64	2350	2½	3
22	200	12	15	5	[illegible]	1⅛	[illegible]	34	2	4¼	4½	3¾	7¼	66	3600	3	3½
30	175	14	17½	5⅞	[illegible]	1¼	[illegible]	39½	2¼	4½	5¼	4¼	8¼	72	6000	3½	4
43	160	16	20	6⅝	1	1¼	[illegible]	45	2½	5⅜	5¾	4½	9¼	82	9500	4	5
57	150	18	22½	7½	1⅛	1⅜	[illegible]	50	2¾	5¾	6½	5¼	10½	96	10500	5	6

The diameters and weights of fly-wheels vary to a considerable extent among engines by different builders to adapt them to special service where the steadiness of speed is a special factor of design.

For electric-lighting purposes, either or both diameter and weight of the fly-wheels may be increased above the tabulated figures, which have been computed for ordinary power service.

The sizes of the inlet and exhaust-valves have been figured for a free inlet and discharge at the maximum speed in the second column of the table. For higher speeds of special motors the valve area should be somewhat increased.

Of explosive motors of the larger units now in the market, we detail in the following table some of their most salient features

as a study of the progress of this class of prime movers for large power instalments:

TABLE XVII.

Builders.	Diameter, Inches.	Stroke, Inches.	R. P. M.	Brake H.-P.	Clearance, Per Cent.	System of Governing	Type of Engine.	Weight. Engine Complete, including Fly-Wheels.	Weight. Per Rated H.-P.	Fly-Wheel. Weight lbs. Total.
Struthers, Wells & Co. (Warren)	21	24	180	300	20	Throttling.	Ver. 2-cyl., 4-cy.	75,000	250	12,000
National Meter Co. (Nash) ..	13 5	16	225	125	19	Hit or miss.	Ver. 3-cyl., c-4y.	28,500	228	{3,600 2,400
The Bessemer Gas Eng. Co.	13.5	20	180	100	14	Throttling.	Hor. 2-cyl., 2-cy.	23,000	230	5,800
Marinette Iron Wks (Walrath)	14	14	250	125	23	Throttling.	Ver. 3-cyl., 4-cy	23,000	184	6,600
The Alberger Co.	17	19	200	125	21	Auto cut-off.	Hor. 2-cyl., 4-cy	25,000	200	7,000
Lazier Gas Eng. Co.	15	21	160	50	20	Hit or miss.	Hor. 1-cyl , 4-cy.	14,000	280	4,000
National Meter Co. (Nash)..	9	11	270	50	22	Hit or miss.	Ver. 3-cyl., 4-cy.	11,000	220	3,600
Westinghouse Machine Co.	18	22	200	300	21	Throttling.	Ver. 3-cyl , 4-cy	95,000	316	8,600
Westinghouse Machine Co	8	10	325	38	21	Throttling	Ver. 3-cyl., 4-cy.	10,500	276	{1,750 1,150

Still larger units and installations are built and in use in Europe and in the United States, for the use of blast-furnace gas. The Cockerill type is now built by the Wellman-Seaver-Morgan Company, Cleveland, O., with single-acting cylinders, for blast-furnace gas, up to 600 brake horse-power, and double-acting up to 1,200 horse-power. By doubling up these units any desired power may be obtained in a single installation.

The double-acting Nurnberg engine is now being built by the Allis-Chalmers Company, with cylinders of fifty-nine inches in diameter; with duplex tandem double-acting cylinders, in units up to 1,800 horse power. In Germany, blast-furnace gas-engines are in use up to about 2,000 horse-power, in unit combinations of double-acting cylinders of forty-one inches diameter by four and one-quarter feet stroke. The low-explosive pressure of blast-furnace gas has greatly favored large cylinder dimensions, and thus given an impulse to the building of large power-motors with the least number of individual units.

CHAPTER XI

GOVERNORS AND VALVE GEAR

THE regulation of the speed of explosive engines has an important bearing upon their usefulness and freedom from constant personal attention. By experience from trials during the few years of the growth of the new motor, much progress has been made in perfecting the details of this important adjunct of safety and uniformity in speed regulation through the action of a governor. There are four principal methods in use for controlling the speed, viz.: (1) By graduating the supply of the hydrocarbon element; (2) by completely cutting off the supply during one or more revolutions of the crank; (3) by holding the exhaust valve open or closed during one or more strokes; (4) in electric ignition by arresting the operation of the sparking device.

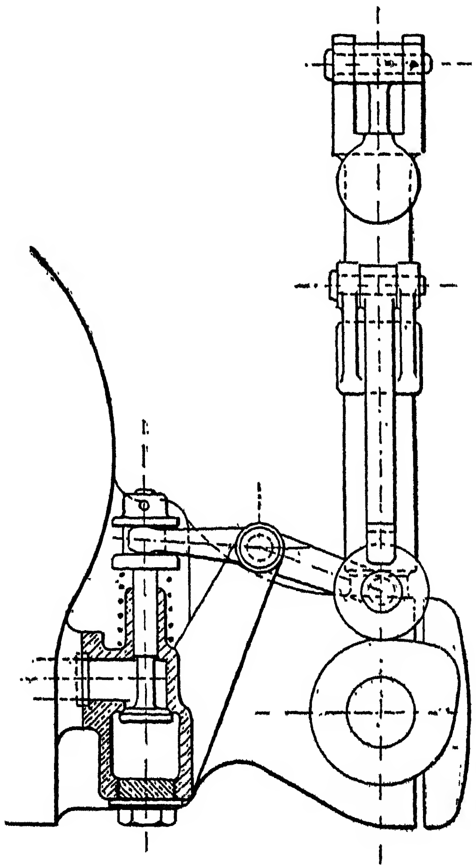


FIG. 48.—The Robey governor.

To vary the quantity of the hydrocarbon fuel by the action of the governor is claimed to be the most economical as well as the

most satisfactory method in use, if the variation in the work of the engine does not carry the charge beyond the limit of combustion; otherwise the second method seems to give the best results.

In Figs. 48 and 49 are two elevations of the centrifugal ball-governor, as used on the Robey and other engines in Europe,

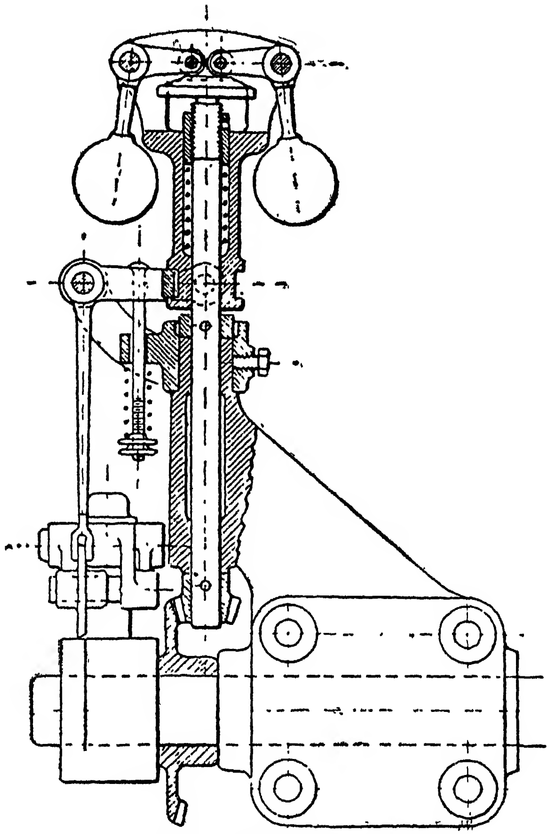


FIG. 49.—The Robey governor.

and adopted with many variations on a number of American engines. In this type the bell-crank arm of the governor, by its centrifugal action, raises or depresses a yoke and sleeve which operates a bell-crank lever with a forked end astride a rotating disk which rides on the cam of the secondary shaft. The disk has a lateral motion on the end of the valve lever, so that the

action of the governor rides the disk on to or off the cam, and thus makes a hit-or-miss stroke of the inlet-valve.

The centrifugal governor (Fig. 50) is another application of the hit-or-miss principle, by the use of a pick-blade operated from the governor by a balanced bell-crank and connecting rod. The cut fully explains the detail of its construction and operation, by which an abnormal speed of the governor pulls the pick-

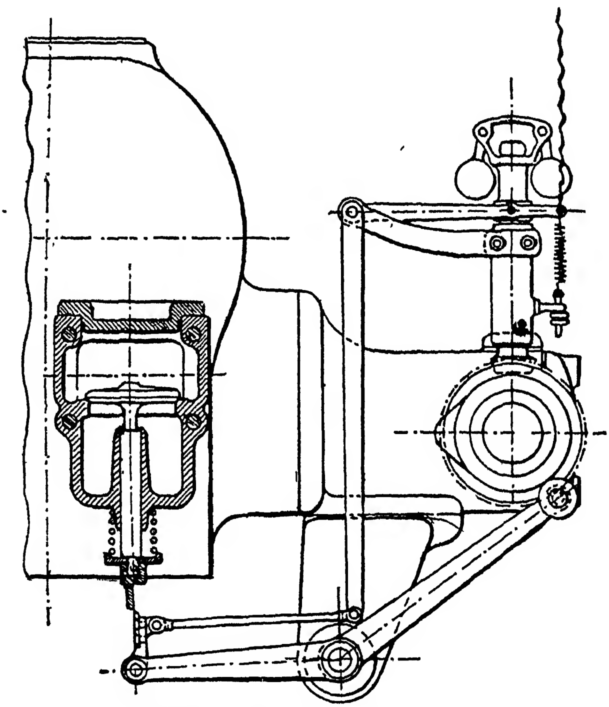


FIG. 50.—The pick-blade governor.

blade away from the gas-valve spindle. In some forms graduated notches are made on the pick-blade or spindle-blade, so that in action the governor gives a varying charge within certain limits and a mischarge when the speed is beyond the limitation.

The inertia governor used on the Crossley engine in England, and with many modifications in use on American engines, is illustrated with plan and elevation in Figs. 51 and 52, in which A is the cam shaft, B the cam, C the roller, D the lever, H the lever-

pin, L the spring to hold the roller C to the cam, J the governor weight, K the adjusting spring, G the pick-blade, and F the valve stem.

In the action of this governor the initial line of motion of the

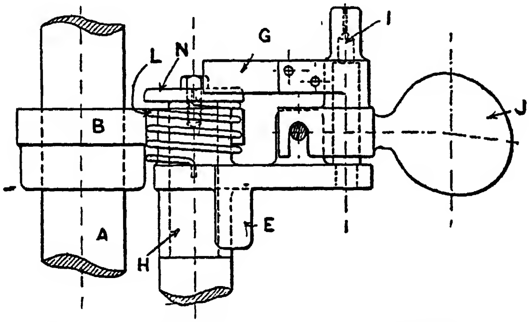


FIG. 51.—Inertia governor, plan. "Crossley."

ball J, in regard to its centre of motion H, is shown by the dotted curved line. By the sudden movement of its pivoted centre L, the ball is retarded in its motion by the regulating spring K, which

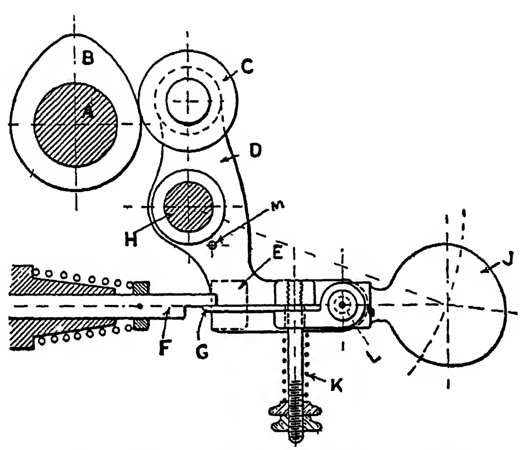


FIG. 52.—Inertia governor, elevation. "Crossley."

tends to throw the pick-blade G off the shoulder of the valve stem F.

It will be readily seen that the inertia of the vibrating ball

will vary as the speed of vibration, so that by carefully adjusting by the spring K, the action of the ball will vary the disengagement

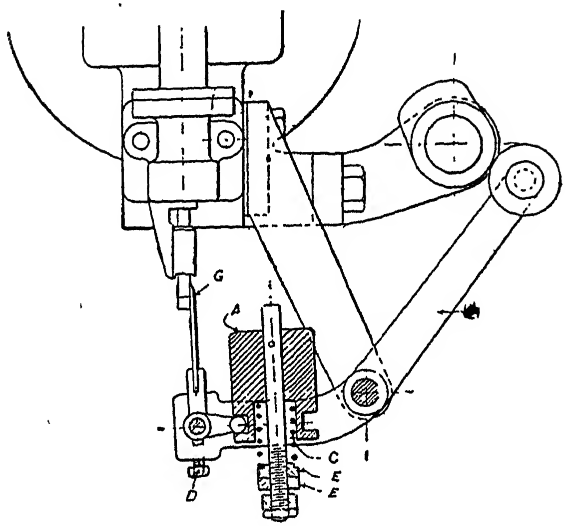


FIG. 53.—The vibrating governor, elevation. "Stockport."

of the pick-blade to correspond with the over-speed of the engine, and make an entire miss at the limit of its variation. The air-valve may also be operated by the spud E.

Another form of governor, involving the same principles of inertia as the last one, is used on the Stockport engine in England, and is illustrated in Figs. 53, 54, and 55. It consists of a weight A, balanced on the vibrating arm B. A groove around the weight operates a bell-crank, to which the pick-blade is attached. The balance spring is adjustable for regulating the position of the pick-blade and its contact with the valve spindle. By the variation in overcoming the inertia of the weight by the spring with different vibrating speeds in the lever, the disengagement of the pick-blade with the spindle-blade is varied or a miss-stroke made.

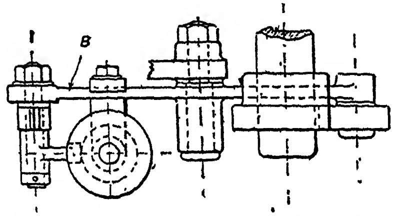


FIG. 54.—The vibrating governor, plan. "Stockport."

The pendulum governor (Fig. 56) is also an inertia governor in the principle on which it operates. It is attached to the exhaust-valve push-rod, and vibrates horizontally with the rod. The weight or ball has an extension or neck, with a pivoted eye, a yoke, and a vertical lug. The eye is pivoted in the box, and the yoke embraces the push-blade stem, which is also pivoted horizontally with the eye in the box or frame. The lug bears on an adjusting spring, which is set up by a screw so as to limit the swing of the ball to the normal speed of the engine, so that when the speed rises above the normal the inertia of the ball holds it back in its vibration and lifts the push-blade out of contact with the valve stem.

In some engines the position of the ball is reversed, and it stands

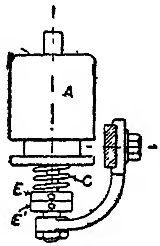


Fig. 55.—End view, elevation. "Stockport."

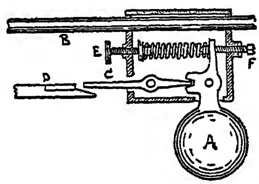


Fig. 56.—The pendulum governor.

above the valve push-rod on a finger and is made adjustable in its length of oscillation by its distance from the fulcrum.

Several modifications of the governors here described are in use, devised on the principles of inertia as illustrated in Figs. 50, 53, and 56.

Apart from the ordinary methods of operating the valves of explosive motors by reducing spur gear and the reducing screw gear for driving a cam-shaft for four-cycle engines, we illustrate in Fig. 57 and Fig. 58 two very simple methods of operating the charging or exhaust-valve by the direct action of a push-rod from an eccentric on the main shaft.

In Fig. 57 the vertical section shows the form of the cam on the central thread of a two-thread worm on the main shaft with the push-rod and valve. The horizontal diagram shows the worm and intermittent ratchet-wheel pivoted in the fork of

the push-rod. At every other revolution of the shaft the cam section of the worm falls into a shallow notch of the ratchet and

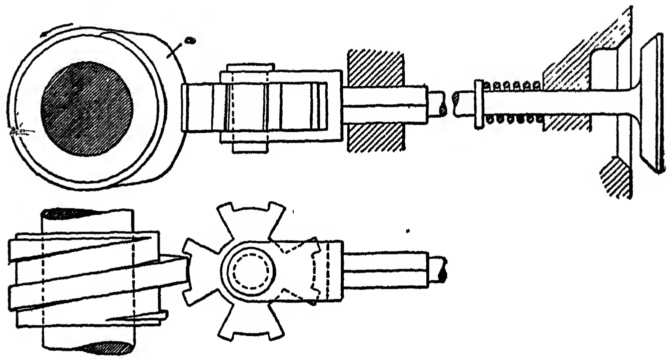


FIG. 57.—The worm cam push-rod.

thus gives a push stroke of the valve at every other revolution of the shaft.

Fig. 58 illustrates another form of ratchet push-rod. In this device the ratchet is mounted on a friction-pin which may be adjusted by a thumb-nut and soft washer so as not to turn back-

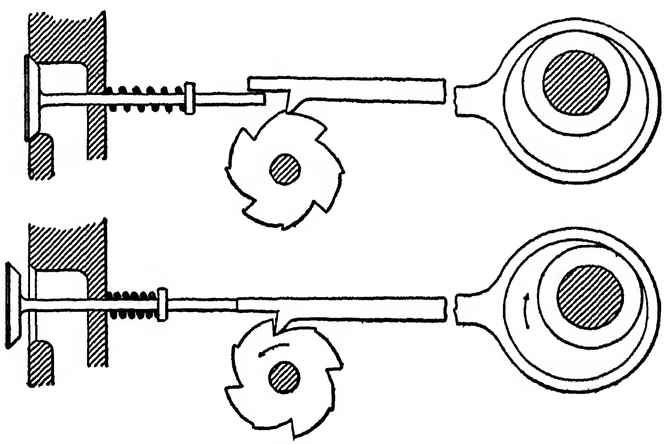


FIG. 58.—The ratchet push-rod.

ward, yet may easily be rotated forward by the motion of the cam-moved push-rod. The upper figure shows the tooth of the

push-rod on the shallow notch and missing contact with the valve spindle; at the next revolution of the shaft the tooth catches the deep notch and makes contact with the valve spindle. The throw of the eccentric should be slightly greater than the distance between two consecutive teeth in the ratchet.

A governor of the inertia or ball type can be attached to the push-rod with a step contact on the valve spindle, making a very simple valve movement and regulation.

The ring-valve gear (Fig. 59) is another way of operating the exhaust push-rod of a four-cycle engine directly from a cam on the main shaft. The inner-ring gear is swept around within the outer fixed gear, skipping by one tooth at each revolution of the engine-shaft.

The outer stationary ring has twice the number of teeth in the

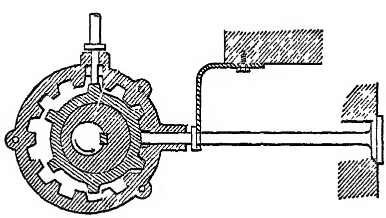


Fig. 59.—Ring valve gear.

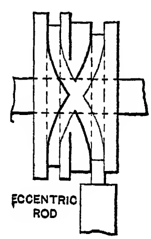


Fig. 60 —Double-grooved cam.

ring gear, plus a hunting tooth, which makes a contact of a ring-gear tooth with the exhaust-valve rod at every other revolution.

A double-grooved eccentric (Fig. 60) is another method of operating the exhaust-valve of a four-cycle engine by traversing the push-rod end, in the grooves which cross each other on one side of the cam; the groove on one section of the cam being enough smaller than the groove on the other section to give the valve its direct proper movement.

The pendulum governor (Fig. 61) is a simple and unique arrangement derived from the musical beat pendulum. It is hung in a frame that is attached to and vibrates with the push-rod. The swing of the pendulum is adjusted by the distance of the small compensating ball from the centre of motion to vibrate synchronously with the push-rod at the required speed of the engine. In-

creased speed increases the range of vibration and releases the curved pawl of the push-blade C and catches it again at the next stroke.

The differential cam (Figs. 62 and 63) is much in use on the Otto engines in Europe and the United States. It is also called

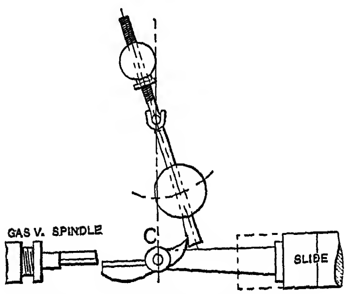


FIG. 61.—Pendulum governor.

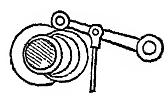


FIG. 62.—Differential cam.

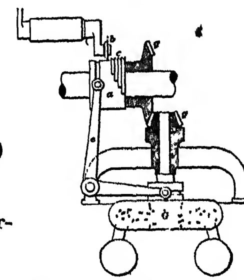


FIG. 63.—Differential cam governor.

the step cam and is made for from closed to four grades of valve lift with corresponding differential charge. The centrifugal movement of the governor-balls slides the sleeve on the governor-shaft and through the bell-crank lever the step-cam sleeve *a* on the valve-gear shaft. The disk-roller *b* on an arm of a rock-shaft, rolls upon one or the other cam steps at *c*, thus varying the movement of the inlet-valve, which is connected to another arm of the rock-shaft. The tread of the roller *b* is beveled and the steps of the cam are also beveled to match, so that the roller cannot slip off the cam.

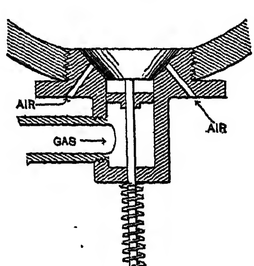


FIG. 64.—Double port inlet valve.

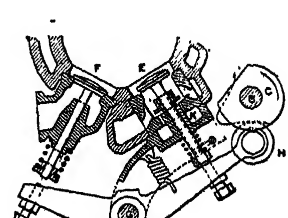


FIG. 65.—Valve gear.

The double-port inlet-valve (Fig. 64) is one of the methods of mixing the charge of gas or gasoline and air directly into the cylinder. It is made in reverse design and with a groove around

one or both the valve disk and valve seat, so that the gas or gasoline may be injected through the seat or from beneath the valve.

In Fig. 65 is shown a gas-engine valve gear in which both valves are operated by an inlet and an exhaust-cam through a bent lever. The form and set of the cams give the proper time action and the set-screws in the lever adjust the lift of the valves. E is the inlet-valve; F the exhaust-valve; C, a double cam with groove that rides the sliding roller H alternately on to the inlet and exhaust section. The inlet-valve is double seated, the small flat disk covering the gas inlet from the chamber K, the air inlet being between the disks.

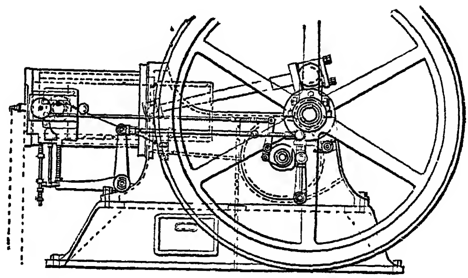


Fig. 66.—"Union" valve gear.

The "Union" valve gear (Fig. 66) has a double push-rod. The one for the charge is operated by a cam on the reducing gear with a straight lever to bring the rod in line with the valve. A second cam and lever for the exhaust-rod changes the direction of the push by a bell-crank.

The governing device of the Ruger and Olin gas and gasoline-engine is of the centrifugal type and consists of two weighted

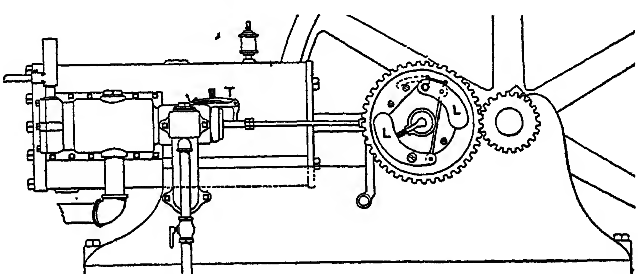


Fig. 67.—Centrifugal governor.

levers L, L (Fig. 67), which operate a small bell-crank and adjustable spindle which rides the push-roller on to or off the exhaust-cam, thus holding the exhaust-valve open during excessive speed.

CHAPTER XII

EXPLOSIVE-MOTOR IGNITION

THE devices for firing the charges in explosive motors have been of many types and designs through the decades of their development; but the early forms using outside flames and sliding ports having been generally abandoned in favor of newer devices, we have therefore omitted their illustration in this edition.

The successful operation of the explosive motor depends very much on the perfection of the ignition outfit.

The outside flame gave way to the hot-tube system, which we represent but do not recommend, as it seems to be fast fading in favor of the methods of electric ignition, which seem to fulfil all the requirements for rápid and accurate ignition, as well as for the time adjustment so essential in high-speed motors. For stationary motors many manufacturers still supply both hot-tube and electric combination for gas-engines and a few for gasoline-engines.

HOT-TUBE IGNITERS

Much of the difficulty in maintaining a constant and uniform explosive effect from the hot tubes used in the early or experimental period of the explosive motor was due to the inability to know or see what was the exact condition of the progress of combustion which was taking place within the tube and passage to the combustion chamber of the cylinder.

The want of a durable and inexpensive material for the ignition-tubes was an unsatisfactory experience in the early days of the explosive motor. The use of iron, with its uncertain and perishable nature, under the intermittent high pressure and at the continual high temperature of the Bunsen burner, oxidized the tubes on the outside, making them thin, so as to burst in a month, a week, or a day; but only occasionally a tube would last

a month, although by the use of extra-strong iron pipe their life has somewhat lengthened. One of the principal causes for the short life of the iron tube may be found in the management of the Bunsen burner. A tube of iron or any other metal should not be used at a white heat even at any one spot. A uniform band at a full red heat all around the central or other part of the tube suitable for timing the ignition is the most desirable temperature for ignition, and for the lasting quality of the tube. In the construction and setting of the Bunsen burners, the point of greatest heat in the flame is too often made to impinge directly against the tube, heating it to a white heat at one spot. This causes a change in its molecular condition, weakening it by crystallization and oxidation, when, in a short time, the constantly repeated hammering of the explosions bursts the weakened metal.

Porcelain tubes are free from the oxidizing properties of metals, but require considerable care in fastening them in place. When once properly set their wear is imperceptible, and if not broken by accident, they seem to stand the pressure well and have a life of a year or more at the trifling cost of from 20 to 30 cents for the sizes ordinarily used, and in quantity at a much lower price.

The usual lengths of porcelain tubes as made by the R. Thomas & Sons Co., East Liverpool, O., are 6, 8, 10, and 12 inches in length. Pass & Seymour, Syracuse, N. Y., also manufacture procelain tubes for explosive engines.

The best metallic tubes now on the market are made from the nickel-alloy rods imported from the Westfälisches Nickelwalzer in Swerte, Germany. The rods are furnished in about 6-foot lengths, of sizes $\frac{3}{8}$, $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, and $\frac{11}{16}$-inch diameter. Herman Boker & Co., 101 Duane Street, New York, are the United States agents. They keep the rods in stock, and also furnish the finished tubes of sizes to order.

This metal is now largely in use by the leading gas-engine builders in the United States, and its lasting quality has been amply tested by more than a year's wear, and in some cases two years' wear for a single tube. The only trouble or shortening of the running time of the nickel-alloy tubes has been from excessive heating and from sulphurous gas, such as the unpurified producer-gas, and in a few instances from sulphurous natural gas,

against which the porcelain tubes seem to be proof. The drilling of the nickel-alloy tubes requires considerable care in order to keep the drill centred in the rod, which is best done by revolving the rod in a dead-rest and feeding the drill by the back centre. Drills should be hard and kept sharp. Use milk for lubricating the drill.

The running out of the drill will make a thin side to the tube, which will be liable to overheat, and by expansion and contraction, due to unequal temperature, will cause the thin side to bulge and finally rupture.

Platinum tubes have been used to considerable extent in Germany and a few in the United States; their cost will probably send them out of use in view of the lasting quality and cheapness of the nickel-alloy and porcelain tubes.

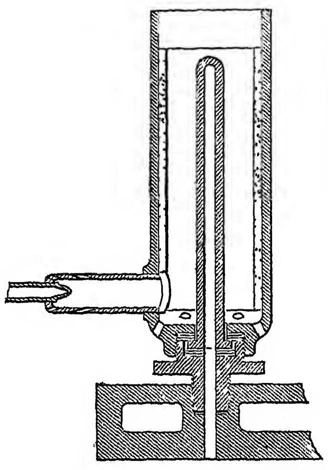


Fig. 68.—Porcelain-tube setting.

In Fig. 68 is shown one of several methods for setting the porcelain tube in a socket to be screwed into the cylinder.

The packing may be asbestos washers, dry or moistened with wet clay.

The application of a new device for hot-tube ignition as used on the Mietz & Weiss engines, by which a short and plain porcelain or lava tube, open at both ends and set between sockets with asbestos packing, has made a marked progress in simplifying the care and adjustment of tubes and time of firing.

A reënforcement of the combustion passage of this device by an iron-pipe extension enlarges the power of the small hot tube by prolonging the burning of the firing charge, and thus making a short tube available to meet the requirement for timing adjustment. Such tubes should last indefinitely; they are cheap, quickly changed, and easily cleaned.

The hot-tube igniter (Fig. 69) shows a view of an ignition-tube used on the Robey engines, which is adjustable for the position of

the igniting surface of the tube as well as for the position of the Bunsen burner, being combustion chamber, igniter passage, and Bunsen burner pivoted to the chimney frame, which allows the

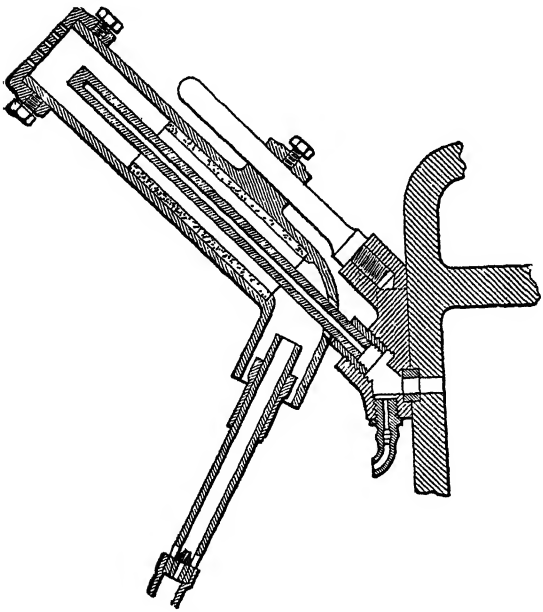


FIG. 69.—Adjustable-tube igniter.

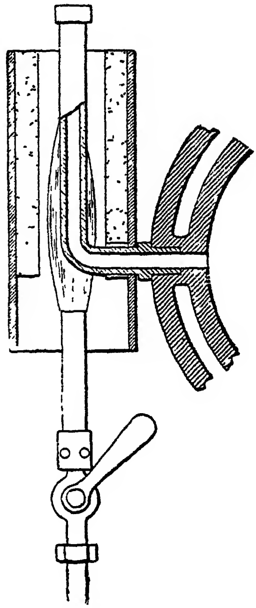


FIG. 70.—Bent-tube igniter.

burner to be tilted slightly to regulate the distribution of the flame around the tube.

The set-screw in the chimney socket allows of a ready adjustment of the position of the chimney and burner for the time of ignition. Fig. 70 shows a bent-tube igniter of German model.

IGNITING TIMING VALVES

The value of an exact time of ignition for producing uniformity of speed in explosive engines is attested by the exhaustive experiments of years with the many devices made for the ordinary tube igniters, and the final recourse to electric ignition. A satisfactory result has been obtained in several designs for operating a valve at the mouth of the ignition-tube that admits the compressed charge to the ignition-tube at an exact point in the piston-stroke.

In Fig. 71 is illustrated a timing valve used on the Robey engine, in which A is the combustion chamber; B the passage leading to the hot tube, a double-seated valve and spindle held to its front seat by the spring D; E a lever operated from the cam shaft; F adjusting spool with set-nuts. In action the valve is opened at or about the end of the compression-stroke and kept open during the exhaust-stroke, thus clearing the ignition-tube uniformly and insuring exact time of ignition.

In Fig. 72 is illustrated a combined timing-valve igniter and starter, as used on the Stockport engines. In this arrangement

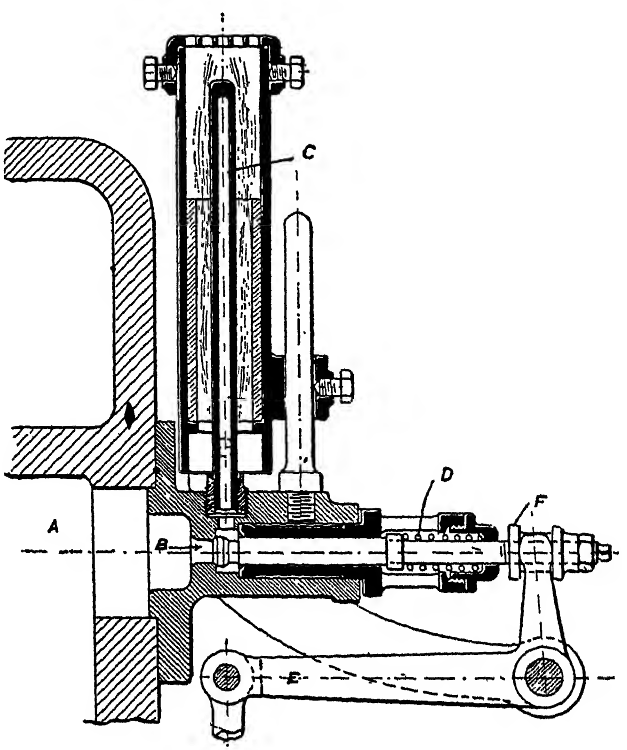


Fig. 71.—Timing valve. "Robey."

a double tube is used, with an annular space between the inner tube and the hot tube, through which the products of combustion may be blown out, followed by the explosive mixture, into the hot tube, by compressing the timing valve and the starting valve at

the same moment. Referring to the cut, F is the timing valve, operated by the lever D; A the starting valve, with its waste outlet at V; H is a mantle to draw the flame closer to the igniting tube.

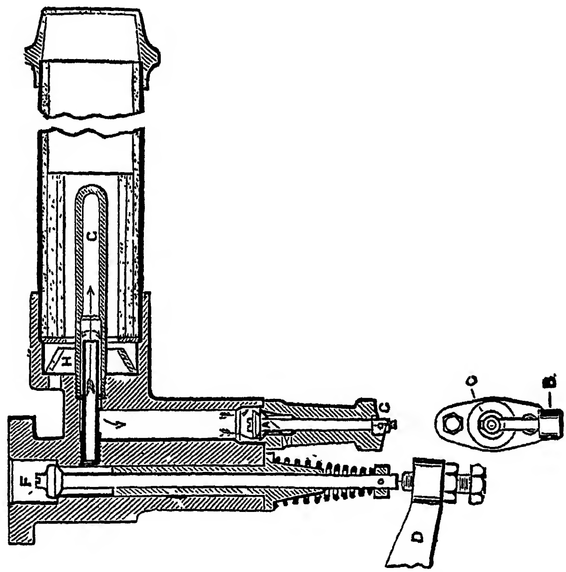


FIG. 72.—Timing valve and starter. "Stockport."

There are many variations in form and attachments for timing valves in use in Europe and the United States. They are much in favor for hot-tube igniters for the larger gas-engines.

IGNITION DEVICES

The ignition devices have been a puzzle to motor builders and operators during the decades of explosive-motor development, and so-called improvements are still in vogue. For gas-engines, tube ignition has had its day for want of a better way and is still in use to a considerable extent, probably because it is simple and cheap to make; but the short life of the tubes when made of iron has made this material unreliable and the resort to a nickel alloy and porcelain has bettered the condition which still has its annoyances.

Electric ignition has become the most reliable and is easily

managed and adjusted to meet the requirements for timing. In its best designs it has been largely adopted by motor builders, and has become a favorite with motor engineers. Notwithstanding the troubles with early designs of electric igniters, from unseen causes due to the hidden position of their vital parts, the later improvements have brought their action to almost a positive condition.

Of the types of electric igniters in use, the break-contact or hammer type involves the motion of a spindle arranged as a rock-shaft with a contact-arm or hammer acting upon a stationary electrode, or a vibrating spindle passing through the walls of the cylinder to make contact with the same hammering force, or, as in a late improvement, to dip into a small mercury cistern. The hammer type, whether it involves the action of a spring to cause a draw break-contact or by a direct-face contact, is subject to wear that either changes the adjustment for timing or prevents ignition by enlarging the contact-faces to such an extent as to allow the spark to occur before the charge can pass in between the faces. Many igniters of this type are made with broad-faced hammers, which become fouled or are so tightly faced by the hammer action that the spark passes before the gas charge can reach the spark between the faces, causing misfires.

This has been remedied by reducing the size of the contact-faces and rounding their surface, which serves to give free access of the explosive charge to the spark at the moment of break of contact.

The single wire-wound sparking coil and battery seems to be the most suitable means for storage of electric current for the internal break-contact igniter.

The jump-spark igniter is increasing in favor among engineers and operators, owing to the simplicity and fixedness of its cylinder terminals, which places the intermittent action on the outside of the cylinder, thereby allowing of ready observation and adjustment without stopping the motor. In the early form of the jump-spark igniter with both terminals passing through a single insulation in the plug, the space on the insulated face of the plug was made so short that by the fouling of the surface the electric current was short-circuited and no spark was produced; this gave much

trouble from the necessity of frequently removing the plug for cleaning the insulating surface. Its construction has been modified so as to increase the distance between the terminals by an extension of one of the terminals from the body of the plug, which is an improvement, but still defective. A later improvement has been made by extending the porcelain insulator beyond the face of the plug from a half to three-quarters of an inch and extending the opposite terminal from the face of the plug with a hooked end and clearing the insulator by a quarter inch, thus giving more than three-quarters of an inch of insulating surface between the electrodes. In some motors the plug terminal is a single positive electrode, while the negative electrode is fixed to the cylinder-head away from the plug, making a greater distance over which short-circuiting has to pass, but this is a mistake, for the insulated part of the plug is the limitation of short-circuit possibilities.

The jump-spark system of ignition requires a secondary or induction-coil, and, for further efficiency, a condenser with a breaking device operated from the valve-gear shaft to open the otherwise closed primary coil from which the secondary or jump-spark is generated at the moment of closure for timing the spark.

There are two methods of operating the jump-spark ignition; in one a magnetic vibrator is employed which makes and breaks the primary circuit many times during the open contact of the time switch by the secondary shaft, during which moment a series of sparks is sent across the terminal electrodes in the combustion chamber, thus insuring ignition by repeated sparking.

In the use of the induction-coil without the vibrator, but a single weak spark is produced at the opening and a single strong spark again at the closing of the timing switch, thus giving two sparks; but the first is not considered available, except from a more powerful induction-coil than needed for the vibrating attachment.

The distance or opening between the terminals of a sparking plug is of greater importance than generally considered, as much hidden trouble has arisen from the form and spacing of this important adjunct in the operation of explosive motors.

For a satisfactory effect a four-element battery in series and an induction-coil for sure ignition should give a spark of maxi-

mum range from three-eighths to half an inch, for which the terminals of the sparking plug should be set at from three to four thirty-seconds of an inch apart, or one-quarter of the extreme length of the spark. The voltage for a reliable spark need not exceed one and a quarter volts in each of a four-battery series, equal to five volts, acting through an induction coil consisting of a soft iron wire-core five-eighths of an inch diameter, No. 12 gauge, insulated by a paper-tube spool five inches in length between the shoulders, on which is wound two layers of cotton-covered copper wire, No. 12, B. & S. gauge, well insulated with paper and shellac varnish. For the secondary coil, wind 10 ounces of No. 36 B. & S. gauge cotton-covered copper wire, shellacing and covering each winding with a layer of uncallendered writing paper. See details of induction-coil further on.

A vibrating hammer and condenser adds to the efficiency of the jump-spark igniter.

ELECTRIC IGNITION

Of the two forms of ignition by the electric spark, it has been shown in practice that both the break-spark and jump-spark are equally applicable and efficient for all speeds and on single or multiple-cylinder motors.

The jump-spark method possesses the advantage of mechanical simplicity and the disadvantage of electrical complication, while the break-spark possesses electrical simplicity and mechanical complication. Either method can be successfully used with any of the regular apparatus for furnishing the electric current—that is, the battery, dynamo, or magneto, or combination of dynamo or magneto and battery, providing the complete apparatus is consistently designed.

It is noticed that the jump-spark with battery is meeting with probably the greater favor by American manufacturers, while the European builders are using the break-spark more extensively with the alternating-current magneto, a few with the alternating magneto and jump-spark.

Batteries possess the advantage, over other forms of current generators, that their maximum strength can be used for starting the engine, but the disadvantage that, after the engine is running,

they grow weaker, until they are exhausted. Some kinds can be recharged to advantage; others must be replaced with a new battery when exhausted. The first cost of batteries is low, and their care is fairly well understood by the average operator. The facts that it is impossible to determine in any practicable way just when a battery will become exhausted, and the cost of maintenance, are probably its most objectionable features.

PRIMARY IGNITION-BATTERIES

Much of the success of explosive-motor running depends on the efficiency of the ignition outfit. The usual primary battery and spark-coil do not always give uniform results.

The life of the battery depends on the chemicals of which it is composed; or, in other words, on its ampere-hour capacity; on the number and voltage of cells connected in series; on the internal resistance of the cells; on the speed of the engine and number of hours which it runs per day; on the design of the igniting mechanism—that is, on whether or not the sparking points make contact every, or every other, revolution or only at times when fuel is admitted; on the length of time points are in contact; on the resistance and efficiency of the spark-coil; on the insulation of the sparking plug, and on the resistance of the external circuit.

By ampere-hour capacity of a cell is meant the quantity of current, measured in amperes, which a cell will furnish for a definite number of hours. Thus, a 300-ampere-hour cell is supposed to be capable of furnishing a current of one ampere for 300 continuous hours. Dry cells are not regularly given an ampere-hour rating for the reason that individual cells vary greatly and, moreover, it is difficult to determine their capacity since, on account of rapid polarization on discharge, it is impossible to take a constant, continuous current from them.

The dry battery, which is used most extensively, is reliable and cleanly, but of short life, making it expensive to maintain. It will regain part of its original strength, if allowed to rest after being exhausted; but, when once exhausted, a new battery should be considered a necessity of the near future.

The storage-battery, in connection with the dynamo or direct-

current magneto, forms an ignition system which is almost ideal theoretically, but ofttimes impracticable. The storage-battery is of great strength and is reliable until exhausted, providing proper care is taken of it; but unless it is given more attention than is generally given it will prove a failure. For instance, if it be charged above a certain maximum rate, it will not receive a normal charge, and will therefore become exhausted earlier than it would naturally do. If it be discharged above a certain maximum rate, the battery will not only fall short on its present charge, but on all subsequent ones; and the time of its ultimate destruction is hastened by the excessive discharge rate. If the battery has been allowed to discharge after the voltage has reached a certain minimum indicated by the makers of the battery, generally about one and eight-tenths volts per cell, sulphating and its consequent troubles result. Owing to the nature of automobile work, this last abuse is probably responsible for the bad reputation that storage-batteries have acquired with those experienced with them. The storage-battery should be both charged and discharged through ammeters; and the discharge should be watched with a voltmeter, not to mention tests with hydrometer for specific gravity. It is not practicable to constantly observe these precautions for ignition purposes.

The dynamo system for ignition, with the speed-governing pulley, is theoretically a fine ignition system; and, if operated by one familiar with caring for electrical apparatus, it is a very satisfactory method. This system, however, possesses two very great disadvantages: first, the dynamo generates a direct current of low voltage, necessitating care and attention to be given the dynamo; second, the dynamo must run at a constant speed, necessitating the use of a speed-governing device, which, for the service required, has not proven altogether reliable. The dynamo system will sometimes work perfectly for a very long time, and then fail at a time most disastrous to its operator, without any apparent reason for its stubbornness.

The Edison Primary Battery, formerly known as the Edison-Lalande battery, and exclusively made by the Edison Manufacturing Co., New York, Chicago, and Orange, N. J., is now the leading type for efficiency and lasting quality for primary-battery

ignition for all types of explosive motors. The batteries are made in varying sizes to meet the requirements for stationary, portable,

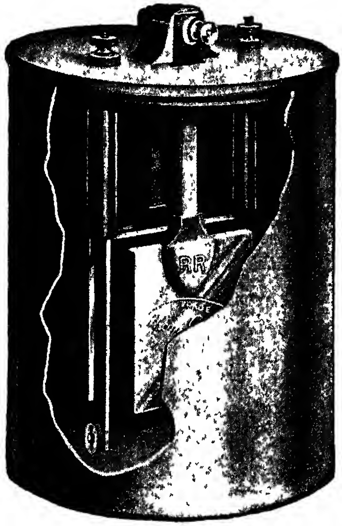


FIG 73.—Type R R, $7\frac{1}{4}$ x $10\frac{1}{2}$″.

FIG. 74.—Type V, $5\frac{1}{4}$ x 8″.

launch, and automobile services. In the construction of these batteries, a double zinc plate forms the negative element and a single plate of compressed oxide of copper forms the positive element of the battery. The fluid is a solution of caustic soda, which is sealed by a layer of paraffine oil to prevent evaporation and creeping of the solution. The plates are all suspended from the cover of the battery, as shown in Fig. 73, which is the largest (or R R) size contained in a porcelain jar, of which five cells, having a capacity of 300 ampere-hours, is the usual outfit of a large motor plant.

FIG. 75.—Type Z, $4\frac{1}{2}$ x $6\frac{3}{4}$″.

For launch motors, the size V is in general use, having a liquid-tight cell of enamelled steel, which will stand hard usage, and of which six cells are sufficient for single or double-cylinder two-cycle or four-cycle motors. On three or four-cylinder motors two batteries of six cells each are recommended, which have a capacity of 150 ampere-hours each

For automobile work, the size Z is recommended for its compact size and less liability to splashing from the vibration of the vehicle. Its capacity is 100 ampere-hours, and from 6 to 7 cells are used for spark-coil ignition. The cell is in a liquid-tight enamelled steel jar.

These various types of Edison primary batteries have the smallest resistance and the most lasting capacity of any primary battery in use.

The sparking coil used with this form of igniter is shown in Fig. 76. It consists of a bundle of iron wire, insulated and wrapped with insulated copper wire. It is a simpler device than the induction or Ruhmkorff coil, but will not project a strong spark or at a great distance between the electrodes, as may be obtained from a Ruhmkorff coil—the breaking device being necessary in either case.

A simple primary sparking coil may be made with a core of iron wire (No. 16) ten inches long and one inch in diameter. Fasten

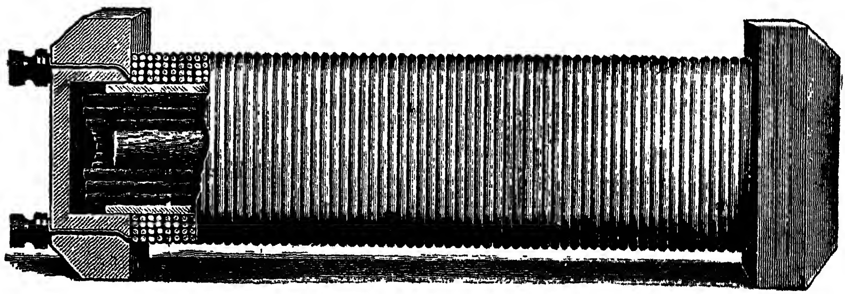


Fig. 76.—The sparking coil.

heads for the spool on this, and cover the core with a few turns of brown paper shellaced to make a tube. Wind No. 14 single cotton-covered magnet wire on this to a depth of about $\frac{5}{8}$ inch, insulating each layer from the next by a layer of paper. Give each layer a coat of shellac also. The coil is used in series with a battery, and the spark is obtained when the circuit is broken. With six or eight strong cells a thick spark will be given. This coil is illustrated in Fig. 76, only instead of four windings make six to eight windings.

The Edison spark coil (Fig. 77) is the result of large experience in an effort to produce the largest spark from the least battery

current. Its short length and large number of wire turns make the magnetic changes instantaneous, producing a hot and powerful spark, so necessary in high-speed motors.

In Fig. 78 is illustrated an ignition-battery plant, in which the batteries may be from three to four in series, connecting with the binding post *p* of the primary winding of the induction-coil T and continued through the other binding post p^1 to the breaker

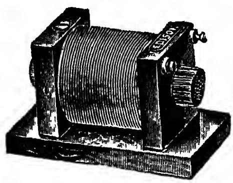


FIG. 77.—Edison spark coil.

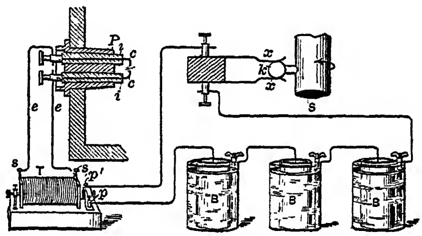


FIG. 78.—Electric igniter.

at *k*, which is operated by a break-contact arm or cam on the reducing gear or shaft.

The secondary winding of the induction coil is connected to the ignition plug P by the wires *e*, *e*, and continued through separate insulating sleeves, *i*, *i*, terminating in the platinum points or preferably small knobs, *c*, *c*. The distance apart of these electrodes should be in proportion to the strength of the current. With an induction-coil and battery of size to produce a half-inch open jump-spark, one-sixteenth to three-thirty-seconds of an inch should be the limit. With three-fourths to one-inch open jump-spark the limit may be one-eighth inch between the electrodes. The primary circuit is made and broken by the passage of the contact piece *k*, between the spring clips *x*, *x*, at the moment required for firing the charge.

DYNAMO ELECTRIC IGNITION

The permanent field dynamo or magneto for producing the ignition current are in favor and are made in a variety of styles. They have a drum armature, enclosed so as to be proof against dirt, oil, and moisture. They can be run by belt or by contact with the fly-wheel with a band of rubber stretched tightly and cemented

upon the dynamo pulley. They are made in several styles and are a favorite for marine and vehicle gasoline-engines.

In Fig. 80 is represented the horizontal magneto as made by the Holtzer-Cabot Electric Co., Boston, Mass. It has a belt or wheel-contact tightening device on a permanent platform. It is their No. 2, or automobile size, which is also best suited for launches. The sparking device for which they are specially designed is the break or wipe spark. This magneto-igniter, while having an armature of the drum type similar to that used in direct-current dynamos, has permanent magnet fields, so that not only is no current wasted to energize them, but the armature can be run in either direction and a wider range of speed employed without

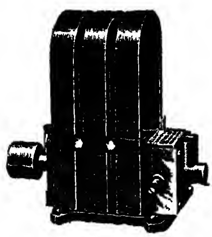


Fig. 79.—Ignition dynamo.

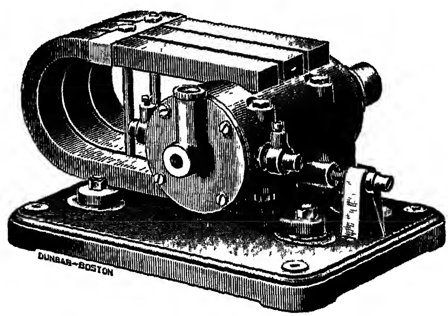


Fig. 80.—Horizontal magneto.

danger of a "burn-out," while a good hot spark can always be depended upon.

The fields of this machine are composed of steel, permanent magnets, and unless subject to abnormal conditions will retain their strength indefinitely. The ∩-shaped bars should never be removed from the fields without substituting an iron keeper across their prongs, and this same precaution should be taken before attempting to withdraw the armature.

Either carbon or woven-wire brushes may be used; the copper brush should be soaked in oil from time to time to prevent cutting the commutator. Carbon brushes will not cut the commutator, but occasionally may become glazed and fail to give reliable contact; when this occurs their ends should be filed off to a new surface, when they will operate as well as new brushes.

The Carlisle & Finch Co., Cincinnati, O., are making a magneto dynamo, the distinctive feature of which is the method of supporting it. It is mounted on a strong pin on which it rocks. This permits of the belt being tightened if it becomes loose, and an adjusting screw is provided for this purpose. The square base or pedestal is to be fastened to the floor, and the tightening screw inserted in the hole on the side toward the engine. This will allow the dynamo to be pushed away from the engine, so as to tighten the belt as it becomes loose.

If it is desired to run the magneto by a friction-pulley, a spring may be attached to the bottom of the magneto, so as to draw it toward the fly-wheel of the engine. In this case, the tightening screw will be omitted. Friction-pulleys are furnished.

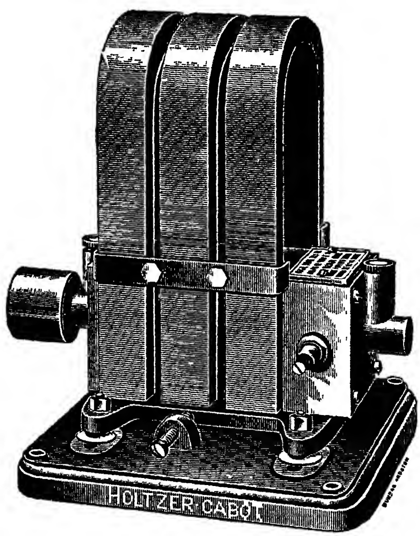


Fig. 81.—Vertical magneto. Holtzer-Cabot type.

The armature is completely enclosed, and the magneto may be sprinkled with water without damage.

For small engines, when the fly-wheel can be turned by hand, it is not necessary to use a battery for starting; but when the engine is so large that it can be turned but slowly, it is necessary to have six or eight cells of open-circuit battery for furnishing the initial spark. Any good type of Leclanche battery will answer. Dry batteries may be used if the magneto is to be used on an automobile where the available space is small.

To meet the wishes of those who have individual preferences for the dynamo type of igniter, and to meet conditions which demand an igniter that will deliver a large amount of energy continuously, as for instance multiple-cylinder engines, the Holtzer-Cabot Electric Company have brought out a dynamo type of

igniter. This new igniter will work through a range of speed from 1,000 R.P.M. to 2,500 R.P.M.; it may be used to advantage in automobile work, it being unnecessary to use any governor whatever. It will deliver a continuous output of 50 watts and will serve under the most severe and exacting conditions. The igniter is pivoted on a sub-base and the belt is tightened or the pressure of the friction-pulley regulated by means of two butt-screws which rock the machine forward or backward as the case may be.

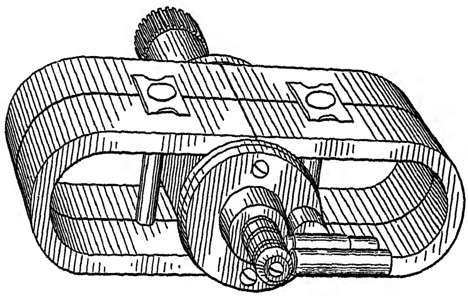


Fig. 82.—The permanent-field generator.

Fig. 82 represents a generator used on the Sumner gas and gasoline-engines. The spark is produced by a plunger contact with the commutator operated from a cam on the secondary shaft.

MULTIPLE-CYLINDER IGNITION

In Fig. 83 is illustrated a dynamo of the Bosch type. The armature A, which is stationary, is provided with two windings, A_1 and A_2, of which A_1 is of stout wire, and corresponds to the primary winding of an induction coil, A_2 being of fine wire and corresponding to the secondary. The changes of magnetism in the armature core, which give rise to the current, are produced by the rotation of a soft iron sleeve B, which partially surrounds it, and is integral with the hollow shaft B_1, which also carries the notched disk B_2, and the high-tension distributing disk D. One end of the winding A_1 is grounded on the shaft of the

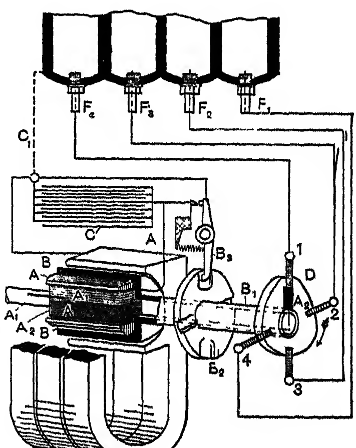


Fig. 83.—Multiple-cylinder ignition.

apparatus, and the secondary winding forms a continuation of the primary. The other end of the primary winding A_1 is led to one side of the contact-breaker B_3, and to one terminal of the condenser, the other terminal of the condenser, and the moving arm of the contact-breaker B_3, being grounded. The sleeve B is slotted, and when the slots come opposite the poles of the field magnet, the armature receives magnetism from the field magnet, and is deprived of it again as the slots pass around, and a powerful current is consequently induced in its windings. The contacts of the contact-breaker B_3 are normally held together by the action of the disk B_2, and during these periods the low-tension winding A_1 is closed on itself, so that a powerful current flows through it at the moments when the magnetism of its core is being varied by the rotating sleeve B. When one of the notches in B_2, which are steep on one side and bevelled on the other, come under the lower end of the contact-lever arm B_3, the latter snaps back, owing to the action of its spring, separates the two contacts, and breaks the circuit of A_1. This produces a high-tension current in the secondary or fine-wire winding A_2, the condenser C increasing the effect. As the secondary winding is connected to the primary as described, and as it is grounded through it, successively connecting the central rods of the sparking plugs F_1, F_2, F_3, F_4 to the opposite end of the secondary A_2, it causes sparks to pass in the four cylinders at the right moments, the tension or voltage of the primary and secondary being added to one another. The distribution is effected by the commutator, or distributor, D. This consists of the rotating disk D, carrying the metal plate A_2, which is in conducting connection with the insulated end of the secondary winding A_2. As the disk revolves, this metal plate makes contact successively with the fixed brushes 1, 2, 3, 4.

THE APPLE IGNITION-DYNAMO

In Fig. 84 we illustrate a neat and compact ignition-dynamo made by the Dayton Electrical Manufacturing Company, Dayton, O. It is entirely enclosed in a case, practically water and dust proof. The pulley has a friction-clutch governor acting on the rim of the pulley and attached to the spindle of the armature. The

clutch shoes of the governor are closed on the rim by the springs, while the centrifugal force of overspeed releases them, and between the action of the two forces, the dynamo runs steadily with a variable speed of the motor.

In the sectional detail of the parts of the Apple dynamo, A is the cast-iron case; B, the hinged cover; C, one of the cast-iron pole pieces of the field magnets, which are fixed to the case by screws as shown; D, the armature, the core of which is built up from thin-toothed disks of soft sheet-iron; E, the coil of one of the field magnets; F, brass bearing; G and H, hard-fibre tubes covering the spindle; K, brass spider and spindle bearing; L, commutator

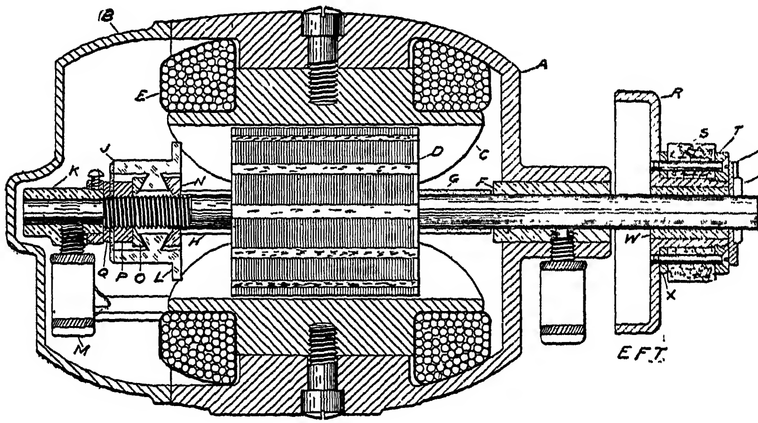


FIG. 84 —Sectional diagram of the Apple dynamo.

with mica insulation; M, wick-feed oil-cup; N and P, bevelled nuts clamping the commutator bars; R, driving disk and rim containing the centrifugal clutch cover; S, pinion fixed to driving disk R and revolving freely on the spindle.

Several forms of internal circuit-breakers have been devised, in which is represented a reciprocating rod which may be operated by a connecting rod with a cam. The insulation is made within a sliding tube, which allows of considerable motion in order to allow the contact piece to slip off suddenly from the stud which is fixed in the cylinder-head.

In Fig. 85 is represented a similar device, in which the insulated rod rotates by an outside gear driven from the valve shaft. The

rotating spindle carries the insulated rod and break-piece eccentrically, so that its contact and break can be accurately regulated by rotating the position of the teeth of the gears.

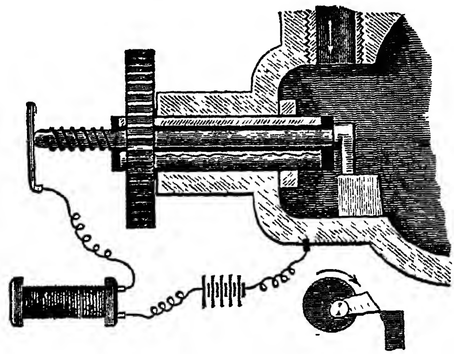


Fig. 85.—Rotating spark-break.

Fig. 86 represents the sparking device used by the Union Gas Engine Company, San Francisco, Cal., and consists of a rocking shaft carrying a flattened pin K on the end inside of the firing chamber, which, by its rocking motion, is brought in contact with an insulated spring S. The spring contact piece, bearing against and rubbing the rocking pin, secures perfect freedom of current circuit while in contact.

The operating device is shown in Fig. 87, where the push-rod R, connecting with an arm moved by a cam on the secondary shaft, is adjusted to make the break contact at the required moment; while the contact spring at M relieves the battery circuit dur ng the time of three cycles.

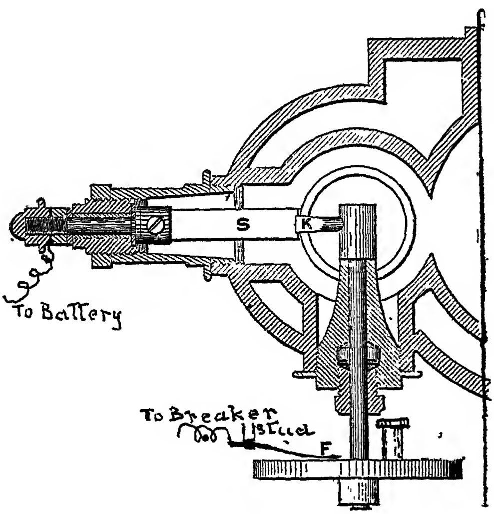


Fig. 86.—Rocking shaft sparker.

Ignition from the current of a small dynamo attached to the engine and driven at the proper speed from the engine-shaft is in successful use and does away with the care of a battery. This requires no induction-coil, the spark being made directly through the break device and electrodes.

A current-breaker used on the Priestman engine is shown in Fig. 88, where an arm kept in position by a spring or weighted

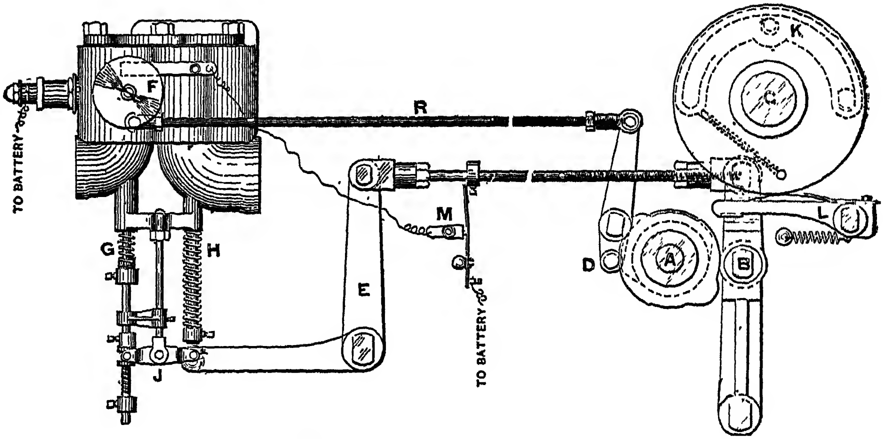


FIG. 87.—The operating device

lever is made to touch a spud revolving on the secondary shaft. A movable sleeve on the shaft is set back or forward for time adjustment of the contact-break.

In Fig. 89 we illustrate a simple and easily made hammer spark-plug which may be inserted through the cylinder-head with a flange-joint, fixed with two studs or tap-bolts. A spring at *s*

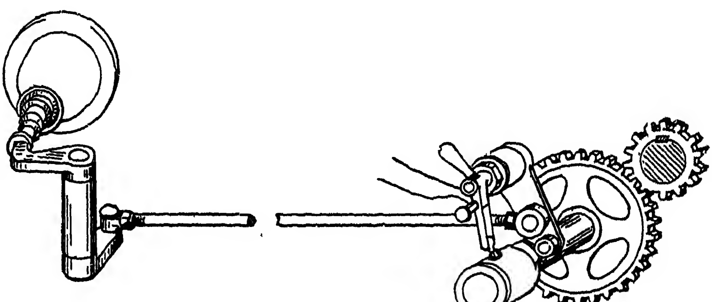


FIG. 88.—The current-breaker.

holds the shoulder of the terminal *a* close to the plug P so that the shaft *b* may have free motion in the plug; *d* is the outside arm rocked by the cam rod.

The fixed terminal is insulated by a lava sleeve which may be in two parts with asbestos washers to prevent breaking of the lava shoulders.

The contact surfaces *x* and *y*, shown in the front view of the plug, should be made of platinum, brazed to the terminals. The method of connecting with the battery and spark-coil is distinctly shown in the cut

In Figs. 90 and 91 we illustrate the details of the mercurial sparker of Mr. J. V. Rice, Jr., Edgewater Park, N. J. It is well

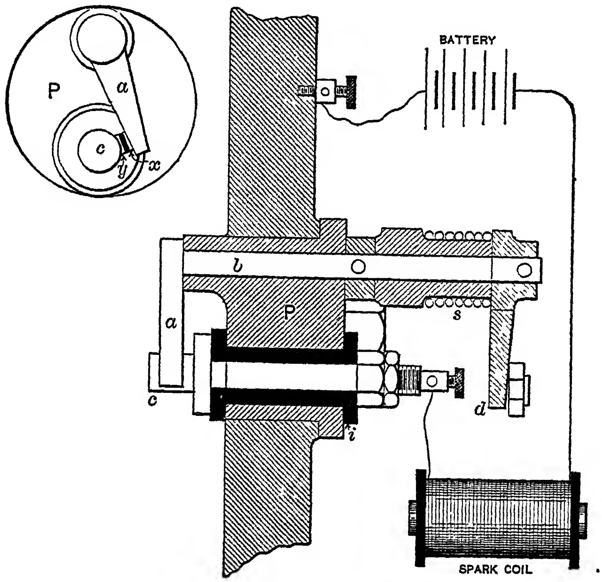


FIG. 89.—Hammer spark igniter.

known that the break of contact with mercury produces a brilliant spark from the electric current, or what is called in gas-engine parlance a "fat spark." This idea has been found in practice to meet some of the faults of the hammer break devices and seems to insure a constant service in this important adjunct in explosive-motor running.

The deep cup of mercury is enclosed in a small water chamber forming part of the cooling circulation of the cylinder, and make-and-break contact is made by the movement of an insulated spin-

dle operated direct from a cam in a two-cycle engine or the reducing shaft in a four-cycle type.

The timing is regulated by screwing the spindle up or down, as shown in the cuts. The connections with a sparking coil and battery, or with a dynamo, are made in the same manner as with other break-contact sparking devices.

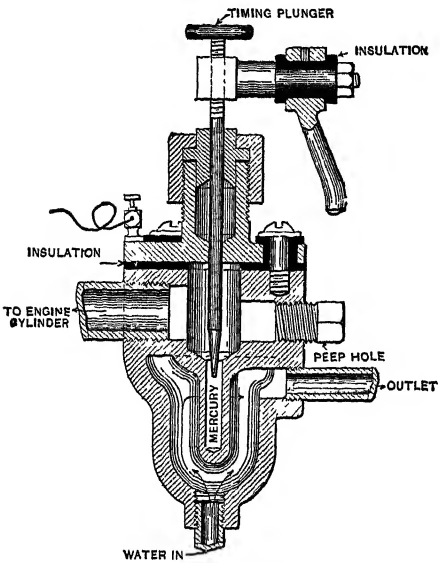


FIG. 90.—The Rice sparker.

The sparker has been in use for many months on a gasoline-engine driving a machine-shop motive plant, a launch, and a high-speed tricycle, without misfires except by control.

The evaporation of mercury from the cell is exceptionally small and does not spill by the jar of the motor. The amount of mercury actually lost in a year's run of a 12 H.P. motor does not exceed 35 cents in cost. High

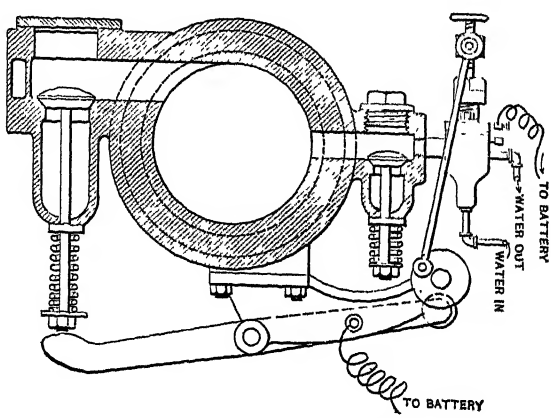


FIG. 91.—Rice valve gear.

speed, which sometimes interferes with the perfect operation of igniters, in a test of this device by the writer, has been found to give a perfect ignition at all speeds up to more than 2,300 revolutions per minute.

In Fig. 92 is illustrated the break-spark controlling device of the Lozier motor.

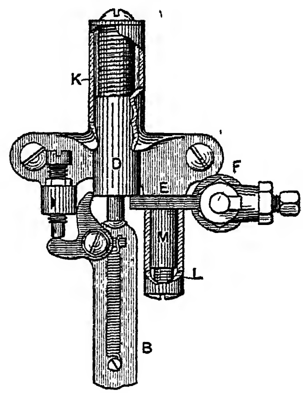


FIG. 92.—Lozier break-spark device.

The motion of the cam-operated rod B, which carries the bell-crank push-blade, regulated by the let-off screw J, lifts the bushing D against the spring K—thus allowing the arm E to be lifted by the spring and plunger L, M, making contact of the break-spark points and establishing the electric circuit. At the desired sparking moment, the rod B and trip disengage the plunger D, and it drops by the force of the spring K upon the arm E, and breaks the contact of the sparking points.

ELECTRIC IGNITION-PLUGS

The Sta-Rite Ignition-Plug is now made by The R. E. Hardy Company, 225 West Broadway, New York City. The special points in its construction make it long lived and a sure ignition device.

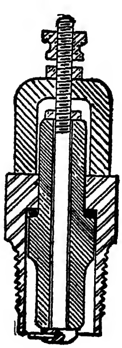


FIG. 93.—Section of plug.

In Fig. 93 we illustrate a detailed section of this plug. As the end of plug entering combustion chamber is much hotter than the outer end, the porcelain is made in two pieces to take care of the difference in temperature. The best porcelain is used and the inner porcelain is turned in a lathe so that the material is much closer and tougher than if made in a die. Ample air space is provided so that soot and oil do not cause short circuiting.

The shoulder of inner porcelain is forced *against* the packed shoulder of shell by the head on the bolt,

instead of *away* from the shoulder. It is, therefore, very easy to keep the plug tight.

The short protected point is not warped out of position by the intense heat.

Flat-steel tension-washers are placed under the set-nuts, so that they do not work loose. These washers, with the vulcabeston packing washers, allow for difference in contraction and expansion between the metal and porcelain parts of the plug.

The shell of plug is made of steel and all exposed metal parts are nickel-plated.

In Fig. 94 is shown the "Standard" plug in general use. This company manufacture a variety of models of their plugs with

FIG. 94.—Standard plug.

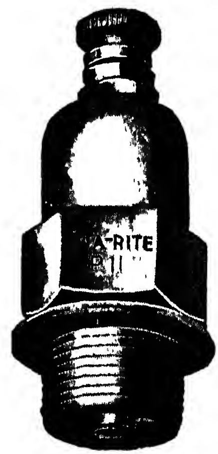


FIG. 95.—Special plug.

½-inch and ¾-inch threads, and short and long shanks, to suit the requirement of thickness of cylinder-heads and valve chambers of marine and automobile-motors, and also to suit the metric threads of imported automobile-motors.

In Fig. 95 is shown an example of a special plug made for the "Thomas flyers."

On the care of the sparking plug, the makers of the "Sta-Rite" have given some details which are worthy of a place here:

"In all forms of gasoline internal-combustion engines, the most difficult and severest duty falls upon the spark-plug, which must resist 350 pounds pressure per square inch, must stand a high temperature (it is exposed to flame under pressure at a temperature of 3,000°), and in addition it must perfectly insulate a high-pressure electric current of from 10,000 to 25,000 volts. It is also exposed to deposits of carbon which tend to allow the spark to escape by providing a path for it to go where the combustible gas cannot get to it, thus causing misfires or total stoppage of motor. The spark-plug is thus seen to be the most important part of the machine, and also the part which most needs to be thoroughly understood and carefully handled. 'Sta-Rite' plugs are designed to fulfil all of the requirements of severe conditions of service, and are also constructed so as to be readily taken apart for inspection, cleaning, repairs, or any other purpose. And when they fail to work properly it is always because of some easily remedied fault which should be sought intelligently and removed. In case of failure to ignite at all, the first thing to inspect is your coil; see that the vibrator works when circuit is on; next, remove wire from top of plug, hold it $\frac{1}{4}$ of an inch from metal parts and observe if spark will jump the gap. It must be capable of jumping at least six times the space of gap between spark points inside, as the resistance of hot gas under pressure is much greater than free air. If spark is weak, a new battery or coil is required; but if this cannot be supplied at once, a plug having shorter spark gap may be made to work, or the one in hand may have gap shortened by turning bolt inside of porcelain (first removing cap and loosening nut), till best position is found. The best distance for most circumstances is $\frac{1}{32}$ of an inch, but with weak battery better results may be secured by a shorter gap. While with strong spark, capable of jumping greater resistance, a more certain ignition is secured by having a somewhat wider gap, it all depends on the power of coil and battery what width is best, and you should never make changes unless sure that you have extra plugs with you, or are certain that you know what the result will be. If the spark is good, the plug should next be removed and inspected for carbon deposit, or cracks in insulation. Carbon deposit will not take place unless you are feeding too much oil, or burning more gasoline than can be completely consumed. If

carbonized, the deposit may be washed out with gasoline or kerosene and a small sliver of wood. If tube is cracked or broken, a new one must be inserted. If sparking end of plug appears all right, the next thing is to remove nuts and cap from top of plug, and see if it is wet or coated with carbon on inside. If wet, it must be wiped dry, and replaced; if black, it must be cleaned, and a new packing inserted inside of steel shell under shoulder of porcelain tube; or else the packing has been destroyed under head of bolt, and must be renewed, which may be done without removing porcelain from shell. If necessary to remove it, same is safely done by swinging entire plug in hand, and striking threaded end of bolt rather sharply against end of wooden box, hammer handle, or other surface which cannot injure threads. When reassembling plugs, care should be taken to replace porcelain tube in same position it formerly occupied, or else change packing for a new one. Otherwise a leak may result. The small nut inside of cap should have an

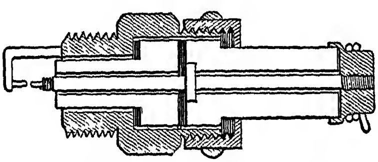


Fig. 96.—French ignition-plug.

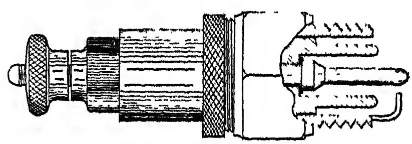


Fig. 97.—Soot-proof sparking plug.

asbestos packing or a spring washer under it to prevent coming loose. The bent washer on top of cap is intended to allow for expansion of porcelain when heated, and should always be placed concave side down under check-nuts and drawn down till about half flattened out. If drawn down solid, porcelains are more apt to break, and the bolt head may be pulled off by expansion when hot."

The ignition of the charge has undergone much change in the past five years in the various appliances and trials which have resulted in placing the electric jump-spark in the lead for reliability and certainty of action. The form of the plug containing the electrodes has undergone many changes in order to eliminate the short-circuit propensities of these simple devices by the carbonizing of the insulating surfaces and to obtain adjustment to meet the abrading propensities of the electric spark. In Fig. 96

we give a section of an ignition-plug of French design much in use on automobile-motors. The plug and nut may be made of hard brass with an extension piece with an electrode of platinum; the spindle of copper with a fixed collar for adjustment and terminating in a platinum blunt-point electrode. The insulation is porcelain or of lava in two pieces with a mica disk between, thick enough to allow of closing the electrodes by splitting off thin slices from the mica disk. The lava insulator can now be obtained from the makers, the D. M. Steward Manufacturing Company, Chattanooga, Tenn.

A soot-proof sparking plug of the Mezger type is shown in Fig. 97 and consists of an annular projection on the end of the porcelain insulator which extends the insulating surface and prevents

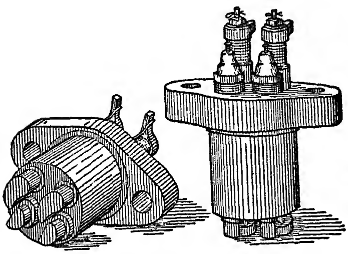


Fig. 98.—Double spark-plug.

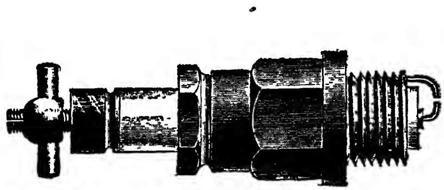


Fig. 99.—The Splitdorf ignition-plug.

short circuiting of the electric spark. These plugs are made by C. A. Mezger, 203 West Sixtieth Street, New York City.

The double-break spark-plug of the Westinghouse Machine Company is a novelty in its line, which we illustrate in Fig. 98.

By a special system of wiring and break-spark connections the double spark may be made simultaneous or successive, a most desirable feature in electric ignition.

The Splitdorf ignition-plug shown in Fig. 99 has a high reputation; the insulation being of porcelain and mica, and the electrodes of iridium and platinum alloy, a guarantee of their lasting quality.

A sparking plug with an extended insulation-cylinder with a crossed-wire electrode has been the subject of a recent patent, in which a double loop of two U-shaped platinum wires crossing each other at right angles at the sparking distance from the insulated electrode, is used in connection with the extended insulation-plug,

and so placed that the inlet charge sweeps across the wires and keeps them cool enough to prevent premature firing. The plug and valve positions are shown in Fig. 100.

In Fig. 101 is illustrated an ignition-plug, the design of Mr. Harry B. Maxwell, Rome, N. Y., in which the terminals are blunt and spherical, which produce a more brilliant spark than plugs with small or thin terminals. In this design it is noted that the lava or porcelain insulating tube extends a distance beyond the iron plug that greatly increases the insulating surface and distance between the metallic parts of the plug. The extension-finger electrode may be made of steel or copper with a cap of nickel or platinum brazed on. The centre-rod electrode with a nickel or platinum cap may fit loosely in the insulating tube with the shoulder packed with asbestos. Asbestos also makes a good and elastic packing for the shoulders of the lava or porcelain tube. The spring and nuts hold the central electrode firmly to its seat and allow for differential expansion.

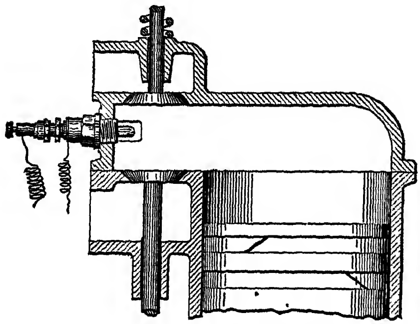


Fig. 100.—Ignition-plug and valve position.

A novel igniter, the invention of Mr. Chas. E. Duryea, and called the "Exploder," is of a design to replace the jump-spark plug with an automatic make-and-break spark mechanism, furnishing a powerful single spark of low tension. The spark is not a series of flashes like those from a jump-spark coil fitted with a vibrator, but the entire force of a primary circuit is given in a single flash, always produced at a predetermined time that remains unaffected by the tone at which the vibrator is pitched.

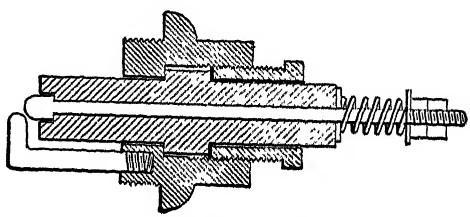


Fig. 101.—Maxwell ignition-plug.

When the circuit is connected the exploder magnet instantly

closes the sparking circuit through the spark-coil, and when the circuit is broken the spark-coil circuit instantly breaks, discharging its full intensity, made even more intense by the discharge of the magnet. The result is a superior spark, with easy starting, great power, steady running, practically no misfire or jerking and straining of the gears, chains, bearings, and other parts.

Any suitable source of electricity may be used, but unless otherwise ordered, the exploders are wound for regular direct-current magneto. From the generator the electric current flows, when connected by the commutator, through binding post to coil of the

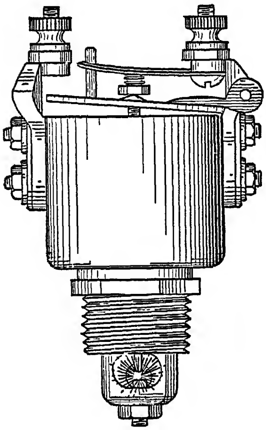


FIG. 102.—The exploder.

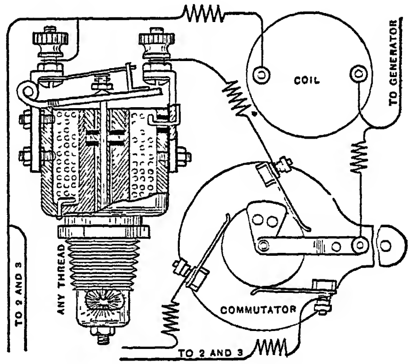


FIG 103.—Section of exploder.

magnet, finally grounding on the shell of the magnet and returning by way of the engine and the ground wire of the generator to complete the circuit. The magnet instantly attracts the armature and forces the reciprocating spark-pin firmly into contact with the adjustable sparking point, thus closing the sparker circuit. This permits a flow of current through the coil, thence to the binding post, and through the armature and sparking pin to the engine and ground wire of the generator. The resistance of the magnet winding is so great that but little current flows through it, which forces almost the entire output of the generator through the coil, thoroughly saturating it. When the magnet circuit is broken by the commutator the armature is released and flies back quickly

under the action of its spring till it strikes the head of the sparking pin, still held in contact by a light spiral spring, and knocks it out of contact with a velocity exceedingly great, due to the extreme lightness of the needle and the rapid movement of the armature.

The entire strength of the current is available to close the contact, and since magnetic pull increases inversely as the square of the distance, the contact is always firm and sure, in spite of oil or soot. Once in contact, an infinitesimal amount of current suffices to hold the armature because of the short distance and the very great pull exerted by the magnet when once closed. This permits nearly all the current to saturate the coil, giving the largest spark possible, even with a weak current. The breaking of the magnet circuit throws all the current through the coil, charging it to the fullest as the magnet discharges, and in addition throwing into the coil the intense discharge impulse of the magnetic circuit, actually compounding the effect.

The spark does not occur until the magnet circuit is broken at the commutator, and this magnet circuit does nothing except close and break the sparking circuit. This insures that the spark-coil is saturated as fully as the source of current will permit, instead of making a spark as soon as the magnet is strong enough to work the armature and before the coil has time to saturate. This device will work with a weak current or a strong one and give the greatest spark possible with either, and in these facts lie its merit.

THE JUMP-SPARK COIL

For a better understanding of the detail of construction of an induction-coil of suitable size for the ignition of the explosive charge of a gas, gasoline, or oil-engine, we therefore illustrate in Fig. 104 the details of such a coil without a vibrator, and in Fig. 105 the same coil with the vibrator. A coil of the size here given and detailed should give a full and hot spark for any ordinary engine across a $\frac{1}{16}$ to $\frac{3}{32}$-inch space between the electrodes. Its full-length spark should be equal to a jump of from $\frac{1}{2}$ to $\frac{5}{8}$ of an inch between wire terminals. The iron core, H, H, is made up of annealed wire, No. 20 wire gauge, 6 inches long, as many pieces as can be pushed into a $\frac{5}{8}$-inch paper tube, $5\frac{3}{4}$ inches

long, made by wrapping paper on a $\frac{5}{8}$ rod with shellac varnish between the layers, say a half-dozen layers, and shellac the outside. Push on to each end of the paper tube a square wooden flange, $\frac{1}{2}$ inch thick, 4 inches diameter, even with the end of the paper tube and square with it. Fasten the wood ends strongly with shellac and shellac their entire surface.

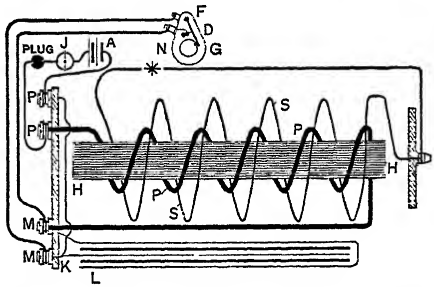


FIG. 104.—Jump-spark coil, without vibrator.

This will then make a spool $4\frac{3}{4}$ inches long for winding the coils. Bore a hole in one of the heads close to the paper tube to pass one end of the primary coil through and another a little farther around to receive the other end. Wind on the spool two layers of No. 16 double cotton or silk-covered copper wire with the ends passed through the holes in the spool flange. Give the coil a coat of shellac varnish and dry. Then wrap the primary coil with three thicknesses of paper with shellac varnish between each wrapping with a perfect closure at the flanges and over the exit wires of the primary. Dry and shellac the outside.

The secondary coil may be made of 8 ounces of double silk-covered copper wire, No. 36 gauge; commencing by passing one end through the hole in the opposite flange from the primary terminals and winding closely but not tight, one layer, shellac and cover with two layers of paper, shellaced, and a third layer at each end to make a sure closure against a spark passing across the layers at the ends of the spool. Continue this back and forward method of winding for the whole amount of wire, covering each layer as the first, and terminate through a hole in spool flange at the same end as it commenced. This should not be a hurried

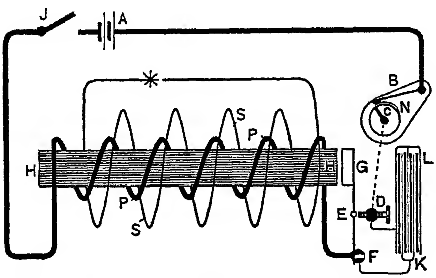


FIG. 105.—Jump-spark coil, with vibrator.

job; give each layer time to dry. The perfection of the whole coil depends upon its thorough insulation, especially at the ends of the layers, where the difference in potential is greatest with a liability of sparking from layer to layer of the coil and the ruin of the work.

Such a coil may be used without a vibrator, and referring to Fig. 104, in which the leading principles of construction are shown, P, P, M, M are the primary binding posts. The upper posts, P and P, are connected through the battery and switch. The lower posts, M and M, are connected through the breaker on the reducing gear from the crank-shaft represented at N, F, D, G. The upper post P, and the lower post M, are directly connected, making a complete primary circuit from the battery A, through the switch J and post P around the core and post M to the breaker at D, and through the lower post M and across by the upper post P to the battery. The condenser L is composed of strips of tin-foil separated by paraffined paper in series and connected at M M as a shunt across the contact-breaker for the purpose of absorbing an extra current induced in the primary coil by the breaking of the circuit, which would tend to prolong the magnetization of the core beyond the desired limit in a high-speed engine.

The condenser may be made of a size to be enclosed in the hollow base upon which the coil is to be fixed, and made up of about 71 sheets of plain uncalendered writing paper, say 5 by 8 inches, dipped in melted paraffine or varnished with shellac on each side; interleaved with 70 sheets of tin-foil, cut 4 by 7 inches, with an ear at one corner of each sheet to project beyond the paper sufficient to allow of the alternate sheets to be connected together on opposite corners. The pile may then be clamped together with 2 pieces of board well shellaced. The ears of each set of 35 sheets may then be pressed together and clamped for connecting to the binding posts M M. Condensers are not absolutely necessary and many jump-spark coils are in use without them. The theory is that the electro-magnetic force of self-induction in the primary, which is principally instrumental in causing the spark at break contact, will expend most of its energy in charging the condenser, causing the break-spark of the primary to be less and the current to become zero with greater rapidity. The practical effect of the

condenser on the spark volume of the secondary is very great, or what is commonly called a fat spark.

The vibrating coil (Fig. 105) is of the same general construction as described, with the addition of a spring vibrator shown at F G. The steel spring G F may be $1\frac{1}{2}$ inches in length and $\frac{1}{2}$ inch in width, fastened to a post at F and fixed to a small armature of soft iron at G with a platinum or, what is better, an alloy of platinum and iridium contact piece at E. D is a brass post with a platinum-iridium-point adjusting screw, and connected to the breaker N and to the condenser K L, completing the primary circuit through the post F, the switch J, and the breaker B.

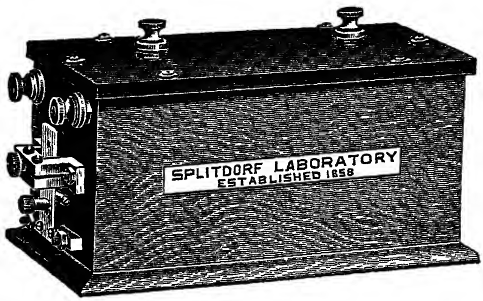


FIG. 106.—The Splitdorf induction-coil case.

The office of the vibrator is to give a rapid intermission of the primary current while the commutator bar C is in contact with the spring B. By this means the induced secondary current also becomes intermittent and so secures a succession of sparks at the electrodes that insures a positive ignition.

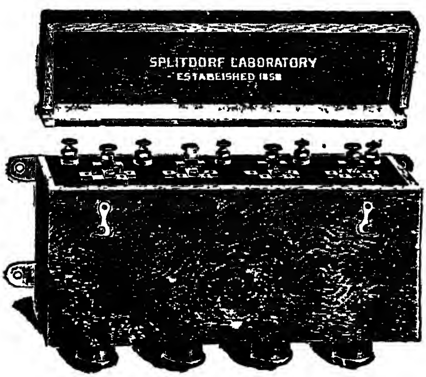


FIG. 107.—Four-cylinder dash-coil.

The complete induction-coil may then be enclosed in a box as shown in Fig. 106, which illustrates a jump-spark ignition apparatus as made and sold by C. F. Splitdorf, 25 Vandewater Street, New York City, who also makes an up-to-date sparking plug and dynamo sparker.

In Fig. 107 is illustrated the four-cylinder engine-dash or vibrating coil, which consists of four vertical induction coils in a single

case. The coils are made by the Splitdorf Company, in one, two, three, and four each in a single case, with cut-out switches as required. They operate at a pressure of from 4 to 5 volts, and need not over 4 dry-battery cells of $1\frac{1}{2}$ volts each for continued use on automobile-motors. The terminals projecting beneath the case are for the spark-plug connections. The post at the right connects with the battery, switch, and motor frame; the four others to the four-part commutator on the crank or cam-shaft.

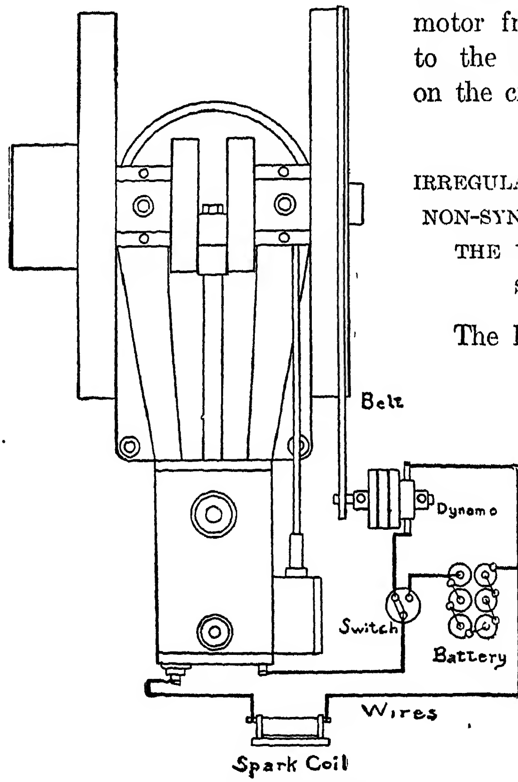


FIG. 108.—Dynamo wiring.

IRREGULAR TIME IGNITION FROM NON-SYNCHRONOUS ACTION OF THE VIBRATOR IN HIGH-SPEED MOTORS

The length and stiffness of a vibrator spring on a jump-spark coil causes considerable variation in its time beat and in this way, by varying the time of ignition, may influence a motor's running not easily observed and this source of trouble may become a cause of anxious search in the action of very high-speed motors. A vibrator may have a possible variation of from 15 to 150 strokes per second, and the sparking time may therefore vary from $\frac{1}{15}$ to $\frac{1}{150}$ of a second.

With a motor running 1,800 revolutions per minute, a revolution is $\frac{1}{30}$ of a second, so that the strokes of the vibrator at 15, 30, 45, 60, and 120, may coincide with the strokes of the motor and their synchronism will produce exact and uniform time sparks.

Any variation in the running time of the motor and the time vibration of the armature will advance or retard the sparking moment; so that for the most uniform sparking effect under the varying speed of a motor, the highest effective speed of the vibrator will give the best results.

EXPLOSIVE-MOTOR WIRING

In Fig. 108 is illustrated the break-spark method of wiring for motor ignition from a dynamo either of the magneto type or the self-exciting field-wound type as before described, which will furnish sufficient current for a good spark at the low speed of 800 revolutions per minute; but for sure ignition at normal speed, the

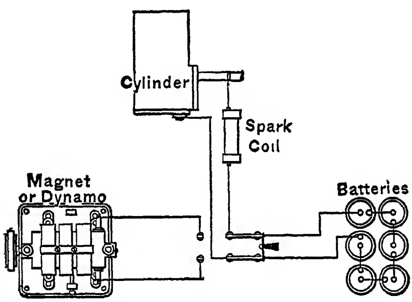


Fig. 109 —Wiring.

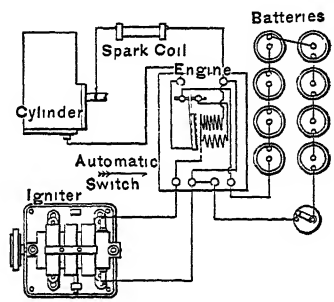


Fig. 110.—Wiring.

motor should run at a speed of about 1,200 revolutions per minute. The break connections are not shown. The usual current is at about 10 volts and 2 amperes.

When an igniter is used in connection with an engine having two cylinders, there should be a separate spark-coil employed for each cylinder, unless a multicylinder timing device is used.

In Fig. 109 are shown the wiring and ignition connections for gas and gasoline-engines, showing battery cut-off switch of double-throw type, location of spark-coil, and current-breaker on engine. If a jump-spark igniter is used, an induction-coil should be substituted for the spark-coil.

In Fig 110 are shown an automatic switch and ignition connections for gas and gasoline-engines, a one-point switch to cut out the battery and an automatic switch so arranged that failure of

the dynamo-igniter current turns on the battery by release of the armature of the automatic switch. On restoring the dynamo current, the automatic switch cuts out the battery.

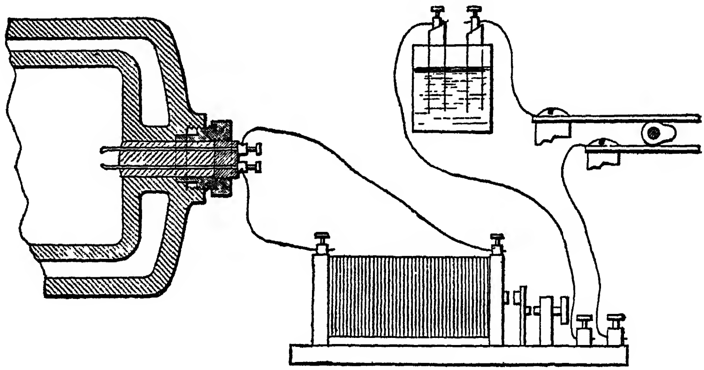


FIG. 111.—Jump-spark ignition wiring, crank-shaft breaker. German type.

Fig. 111 shows the direct connection of an induction-coil and its battery with its crank-shaft breaker. German type.

WIRING FOR A SPARK-COIL

The manner in which wires are connected has considerable to do with the successful operation of an explosive motor, particularly when a magneto is used. It is an easy matter to wire a battery and magneto, and yet successful electricians have been puzzled for the moment over the matter. Whether a magneto or only a battery is used, the wire from the spark-plug on the motor should be connected to the outer winding of wire in the spark-coil. In wiring a magneto (Fig. 112), wire 1 is from the negative pole of the battery to the binding post on the side of the

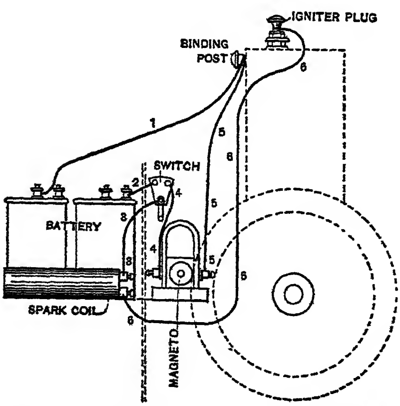


FIG. 112.—Wiring; combined battery and dynamo.

motor; wire 2 is from the positive or zinc pole of the battery to the left side of the double switch; wire 3 is from the centre post on the switch to the inner winding of the spark-coil; wire 4 is from the right pole of the switch to one post on the magneto; wire 5 is from the other post on the magneto to the binding post on the side of the motor; and wire 6 is from the spark-plug on top of the motor to the *outer* winding of the coil, which is easily determined.

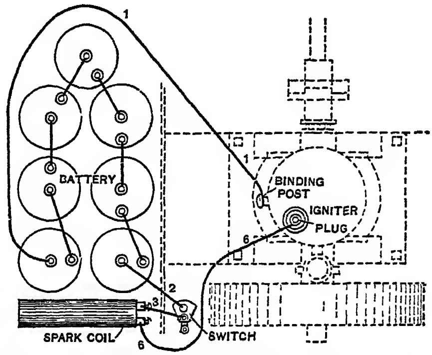


FIG. 113.—Wiring for battery and spark-coil.

In setting a magneto care should be taken to have the shaft of the magneto as nearly parallel to the engine-shaft as possible, so that the armature may work without binding and heating. The friction-wheel of the magneto should be set against the fly-wheel of the motor sufficiently to permit it to be turned

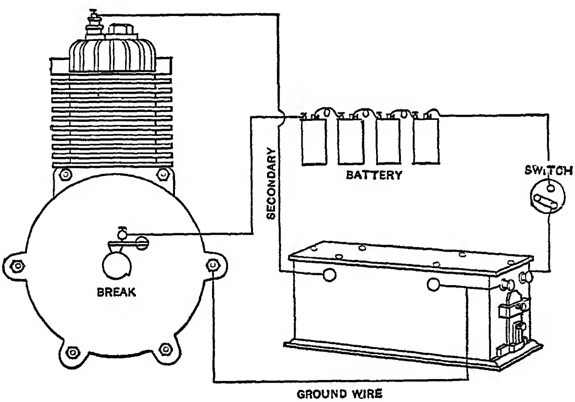


FIG. 114.—Jump-spark from battery.

readily, but at the same time not so close as to prevent it from running easily.

Where the battery alone is used diagram (Fig. 113) may be fol-

lowed, care being used to see that the plug on the motor is connected with the outer winding of the spark-coil.

WIRING FOR JUMP-SPARK

In Fig. 114 are shown the wiring connections of a four-cell battery, switch, and vibrating induction-coil to the shaft-break and spark-plug of a two-cycle vehicle motor.

In Fig. 115 are shown the wiring connections of a combined dynamo, battery, and vibrating induction-coil to the shaft-break and spark-plug of a two-cycle vehicle motor.

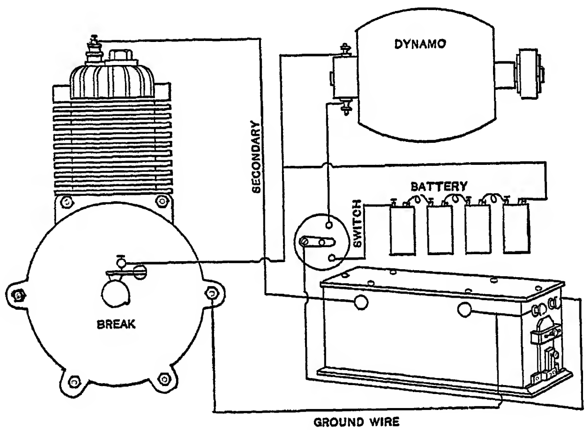


FIG. 115.—Jump-spark from dynamo and battery.

These vibrating induction-coils are made by the National Coil Company, Lansing, Mich.

MULTIPLE-SPARK TIMER

In Fig. 116 are shown a plan and section of a jump-spark timer for four cylinders.

These timers are made by the Pittsfield Spark Coil Company, Pittsfield, Mass., for 1, 2, 3, and 4 cylinders.

The working parts are of steel, the arms being solid steel with coiled springs in the pivot ends which hold the rollers on the hardened steel cam. The cam is pinned by a steel pin to the secondary

shaft of the engine. The contact is made by the cam lifting each arm in turn and engaging the contact surfaces with a slight sliding motion; the contact points are held firmly together by springs until the cam passes and the contact is broken. By means of the slight

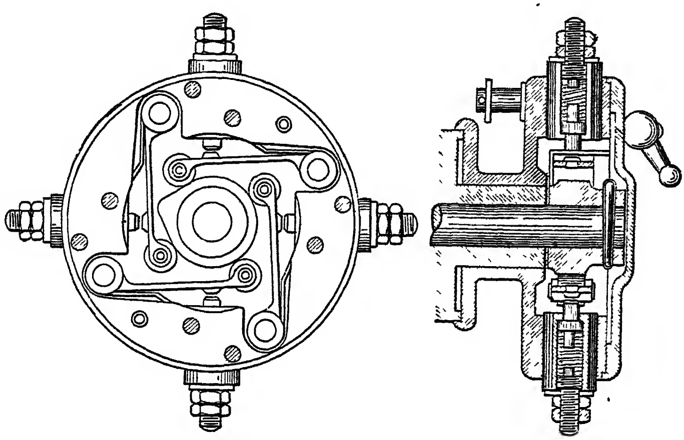


FIG. 116.—The multi-cylinder timer.

sliding motion the contact surfaces are cleaned at each impulse so neither oil, dirt, nor heavy grease will prevent a perfect and complete low-resistance circuit between the coil and batteries during the time of impulse.

CHAPTER XIII

CYLINDER LUBRICATORS AND MUFFLERS

The lubrication of cylinders of explosive motors is a matter of great importance, as the intensely hot gases in immediate contact with the lubricating oil, although the oil is in contact with a comparatively cool metallic surface, have an evaporative effect, tending

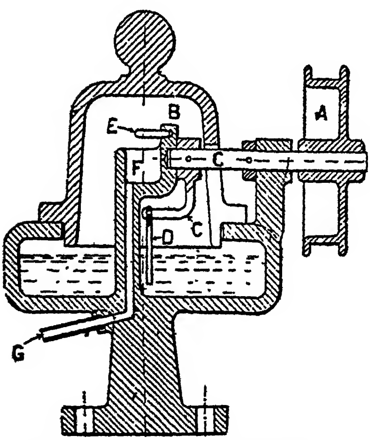


Fig. 117.—The mechanical lubricator. Crossley.

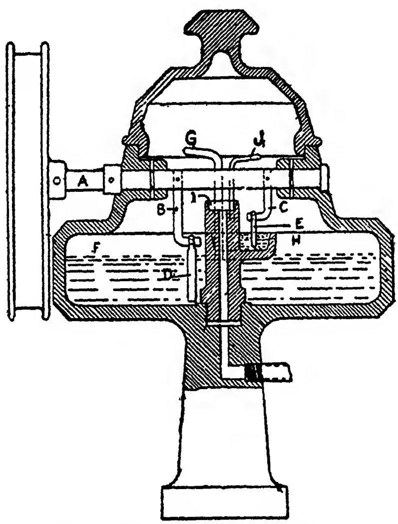


Fig. 118.—The Robey oil-feeder, section.

to thicken the oil into a gummy lining on the surface of the cylinder. To avoid this and keep a perfect lubrication, an oil that is adapted to this severe heat trial should be used and fed to the cylinder walls and piston in constant flow, and not too much or too little, but just enough so that the oil cannot be pushed into the combustion chamber in excess, so as to be blown through the exhaust-valve to clog the passages with oily soot.

The sight-feed and capillary drop-oil feeders have been perfected to such an extent in the United States that they are almost in universal use. Yet on some engines with revolving valve-cam shafts, the facility for obtaining easily the motion for a mechanical lubricator has kept this form in use on many engines.

In Fig. 117 is illustrated a mechanical lubricator used on the Crossley engines in England, and with some variations on other European and American engines. A small belt from the valve-cam shaft to the pulley A gives the required motion to the spindle and crank C C, to which is loosely attached a wire D, that dips into the oil and carries a minute portion to the wiper E, from which the oil drops into the passage to the cylinder.

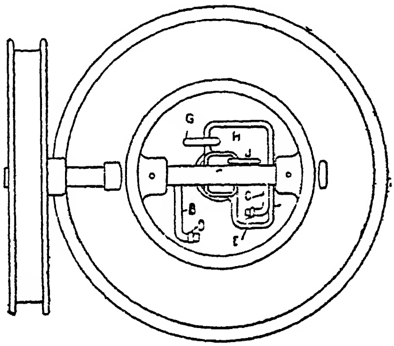


FIG. 119.—The Robey oil-feeder, plan.

In Figs. 118 and 119 are shown a section and plan of a lubricator used on the Robey engines, which is an improvement over the previous one, in that it has a small receptacle above the level of the main oil cistern, which is fed by a revolving shaft and crank arm with drop wire reaching to the bottom of the cistern and wiping the oil on a fixed wiper over the receptacle, from which a second crank arm and drop wire lifts the oil to the wiper that feeds the passage to the cylinder. By this arrangement the oil for the cylinder is drawn from a fixed level, and the feed is therefore perfectly uniform at any level of the oil in the cistern.

Strict attention should be given to the quality of the oil used in the cylinder. Such oil is now made and sold as *gas-engine cylinder oil* of a less density and viscosity than the ordinary cylinder oil, and more fluid, so that it flows readily over the surface of the piston. Such oil does not readily gum in the cylinder and on the piston. It evaporates more readily than heavy oil and in a measure mixes with the explosive charge, and is burned and discharged with the gases of the exhaust, thus avoiding the sooty oil that lodges in the muffler

and exhaust-pipe from the heavier oils. A very small quantity of finely pulverized graphite, used with this oil occasionally, gives good results as a cylinder lubricant and imparts a smooth and glossy surface to both cylinder and piston. For all other parts of the engine the best engine oil is none too good. The poorer grades of machinery oil are not economical at their price.

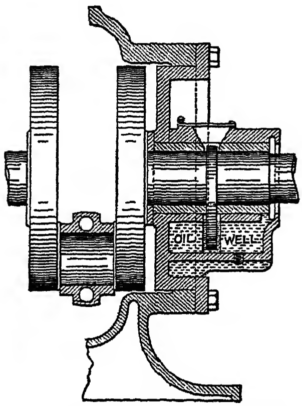


Fig. 120.—The constant oil-feed.

The oil feed to the main journals of a motor is of importance as to its constancy, and has suggested some ingenious devices for this purpose in the form of chain belts and rings running over the journals and dipping into an oil bath. In Fig. 120 we illustrate the ring feed as used on the Mietz and Weiss and other oil-engines. A cavity at the outer end of the journal box returns the excess of oil to the oil-well, as shown in the illustration.

THE GAS BAG

One of the sources of annoyance in operating a gas-engine comes from defective construction of the gas bag. Many times it is either too small or made of material that is soon decomposed by the acid constituents of the gas as now made, when the wrinkling of the bag at the tube connections causes a rupture that is not repairable. We illustrate in Fig. 121 a newly designed gas bag in which the former troubles are avoided by reënforcing the entrance and exit-tube connection with flanges of rubber, so extended as to prevent buckling, and with an enlarged capacity by side gussets, so that the action of the bag has great freedom from the jerky

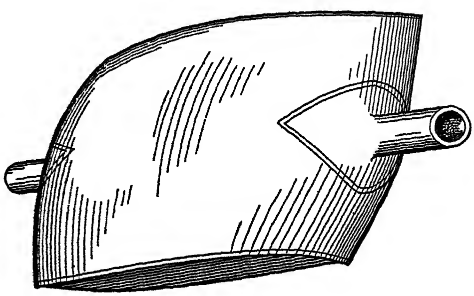


Fig. 121.—The improved gas bag.

Fig. 123 shows a novel muffler of the Thompson type, which has a cylindrical chamber with a hooded spreading inlet-pipe; and a deflector on the exit pipe, by which the exhaust puffs are expanded in the cylinder and issue in a nearly constant stream.

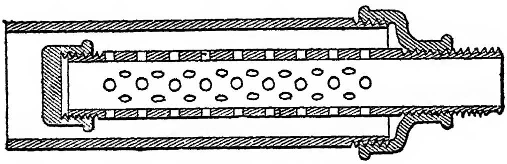


Fig. 122.—Gas-pipe muffler.

Other types of mufflers have strong wire-gauze cylinders within the drum so arranged as to break the impact and disperse the exhaust before it leaves the outer shell.

Mufflers for automobiles and launches have been the subject of much designing in order to have them meet the requirement of almost absolute silence, so much to be desired. The method of perforated tubes with wire-cloth casings of large area for cutting the exhaust into infinitesimal streams, and of so large an area that the back-pressure may be reduced to an imperceptible amount, seems to be in the right direction for vehicles, and an extension of the terminal under water at the stern of launches with a small vent above water has given good results. The vent prevents water drawing back to the muffler when the motor stops. For large stationary motors a variety of designs for the internal space of a muffler-box have been made, all seeming to tend to obtain the desired conditions. A series of perforated plates, both flat and circular; small stones filling the muffler-box, through which the exhaust passes; a spiral case within the muffler-box; in fact, almost any device which tends to stop the sudden impact of the exhaust and its expansion are the means that modify and in a measure prevent the noisy propensities of the explosive motor.

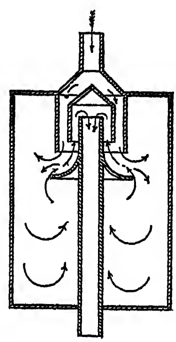


Fig. 123.
Thompson muffler.

To prevent nuisance to neighbors by open-air exhaust, the turning down of the exhaust-pipe into a barrel or second muffler-pot with a few inches of water, has given satisfaction in many cases. It prevents the spread of oil-vapor into neighboring windows.

CHAPTER XIV

CONSTRUCTION DETAILS AND PARTS OF THE EXPLOSIVE MOTOR

THE design of an explosive motor should start from some assigned dimension of the cylinder, based upon the assumed number of revolutions, its required horse-power, and the quality of the fuel to be used. Compression is also a factor to be considered in a nice adjustment of the details for the required power. In Chapter X we have given a few samples of practice among builders of engines as to size, power, and speed, and a table of sizes of the essential parts for a clearance of 33 per cent. and compression of 50 to 60 pounds per square inch. The table represents the actual or brake horse-power, and the sizes of the cylinders and speed are a mean, as in ordinary practice for stationary engines. High-speed motors are a specialty and require some experience for successful designing.

The diameter and stroke of a proposed design must be derived from some assumed mean pressure and speed for the relative conditions of impulse for either of the cycles contemplated. The factors of fuel power and compression are also essential elements of design in construction that need primary consideration. From these data the indicated horse-power may be computed and the actual or brake horse-power obtained from some known mechanical efficiency of this class of motors.

From the many sectional and detailed illustrations throughout this work, the general constructive design of the various models of the two types of motors of the horizontal and vertical styles, and in the stationary and marine class, are sufficiently shown as a guide for the draughtsman and amateur of constructive ability; and together with the computed sizes of parts formulated, should enable any draughtsman of ordinary experience to make a creditable design of an explosive motor.

In Fig. 124 is shown the German method of making the cylinder

and water-jacket in separate castings; the jacket being made an integral part of the bed-frame and bored with aligned bearings to

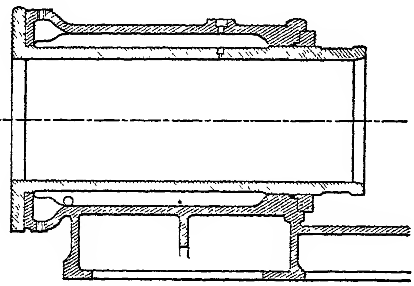


FIG. 124.—The cylinder.

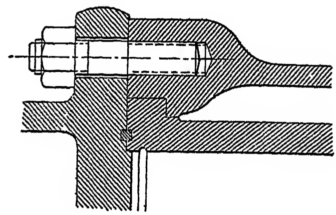


FIG. 125.—Gasket-joint.

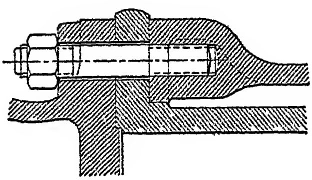


FIG. 126.—Plain joint.

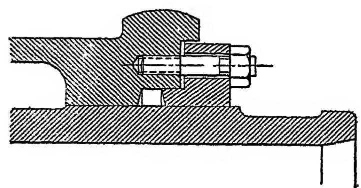


FIG. 127.—Stuffing-box joint.

fit their counterparts on the cylinder. The two designs for bolting the cylinder and water-jacketed head separately to the jacket are shown in Figs. 125 and 126. In one a groove is made to hold a metallic packing, while the other may be a ground-joint or plain gasket.

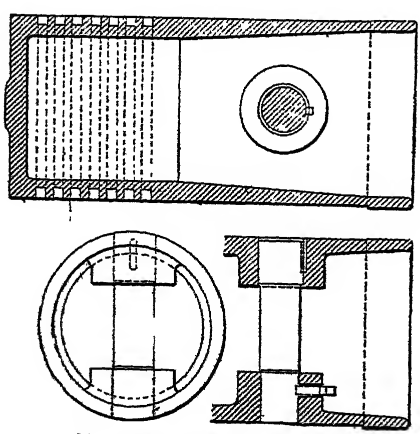


FIG. 128.—The long piston.

In Fig. 127 are given the details of the stuffing-box.

By this arrangement the cylinder is allowed a movement due to difference of temperature between the cylinder and jacket, and yet makes a rigid connection between the cylinder and bed-frame through the jacket.

In Fig. 128 is illus-

trated a section of a piston of German type, nearly two and a quarter times its diameter in length, showing the German practice in regard to the number of rings and their disposition.

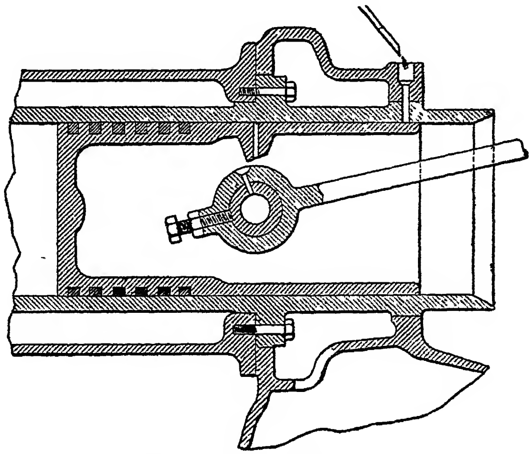


FIG. 129.—Medium-length piston and oiling device.

In Fig. 129 is given another piston of twice its diameter in length, and in Fig. 132 a bushed piston of one and a half times its diameter in length, one and a half diameters for the length of the piston being the average of American practice.

The length of the cylinder must include the assumed length for clearance, less an allowance for protrusion of the piston at the end of the outward stroke, which may be studied from an examination of many sectional views of engine details in the following pages of this work.

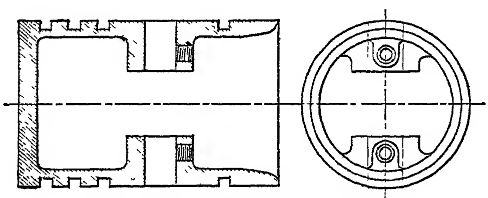


FIG. 130.—Section of short piston.

The short piston in Fig. 130 is nearly the proportion in general use in the United States, with the number of rings varying with different builders.

REPLACING A PISTON

The following plan has been suggested by Mr. E. W. Roberts for easily entering a piston and rings into a cylinder: Take half a dozen or more strips or bands (S, S, Fig. 131), the thickness of which is equal to one-half the difference in the diameter between the bore of the cylinder and that of the counterbore. Slip the piston in part way and then put in the strips. Bend the strips outward, as shown in the sketch, forming a tapered guide which will gradually close the rings as the piston is pushed in. In case there is a port leading into the counterbore these strips will also prevent the rings from jumping into the port. Almost any machinist will realize that this is a very sure and efficient method, and it does not shove the edge of the rings against the end of the counterbore, which is quite often an abrupt shoulder and likely to require much pressure to push the rings past the shoulder of the counterbore.

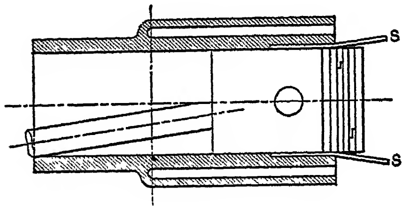


FIG. 131.—Replacing a piston.

The number of piston-rings varies with different builders, the Germans using the larger number. For small engines, three rings

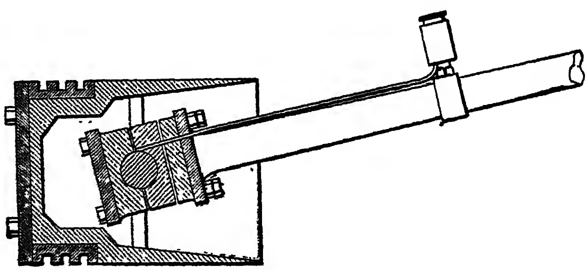


FIG. 132.—Bushed piston and oiling device.

are sufficient, while four are used on medium-sized pistons, with sometimes an extra ring toward the open end of the piston.

The connecting rod should always have an adjustable box at the crank end and in medium and large engines also at the

piston end. Very small engines need only have a solid eye at the piston end, bushed or not as judged best.

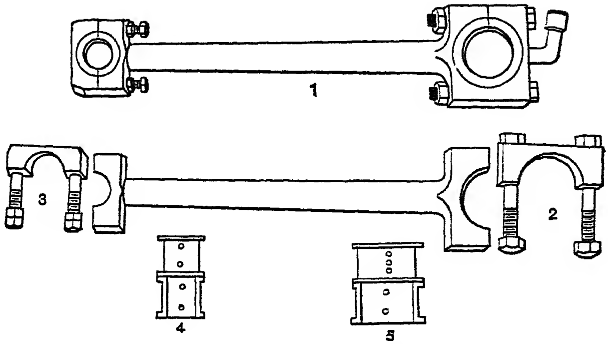


FIG. 133.—Bushed piston-rod.

In Fig. 133 are shown the details of a bushed piston-rod much in use, and in Fig. 134 a box-rod with a strap take-up and keys for the piston end.

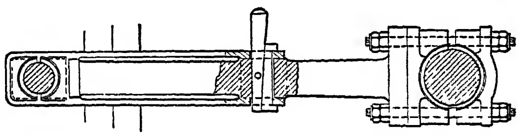


FIG. 134.—Strap take-up piston-rod.

A novelty in the make-up of large vertical motors has been adopted by Struther, Wells & Company, Warren, Pa., in their

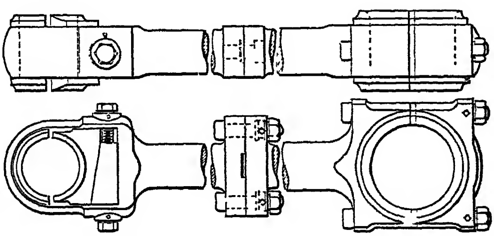


FIG. 135.—The two-part connecting rod.

"Warren Motor." The connecting rods are made in two parts, as shown in Fig. 135, joined by a heavy bolted flange near the centre

of the rod, which allows the piston to be taken down through the bottom of the cylinder for inspection and repairs without disturbing

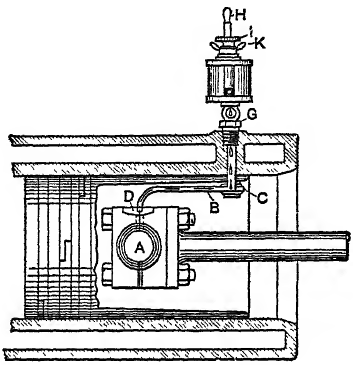


FIG. 136.—Piston-pin oil-feed.

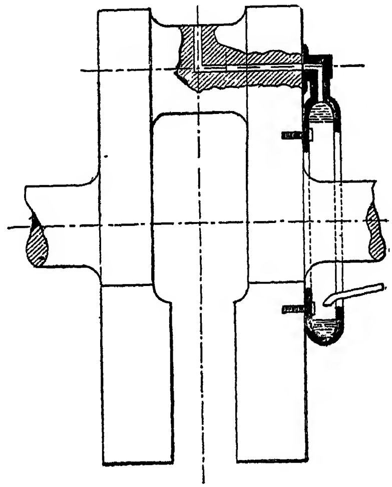


FIG. 137.—The crank oiling device.

the cylinder-head and valve gear, which is attached to the cylinder-head.

In Fig. 136 is shown the piston-pin oiling device used on the engines of the Capital Engine Company, Indianapolis, Ind.

A small tube B, extending from the oil-cup C, and attached to

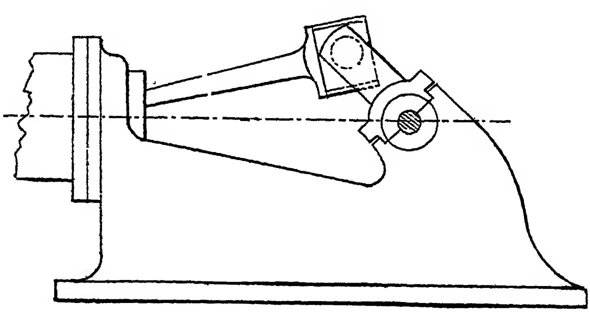


FIG. 138.—The base frame.

the oil-port in the piston, conveys the oil to a recess in the connecting-rod box at D. The recess is long enough to receive the oil in all

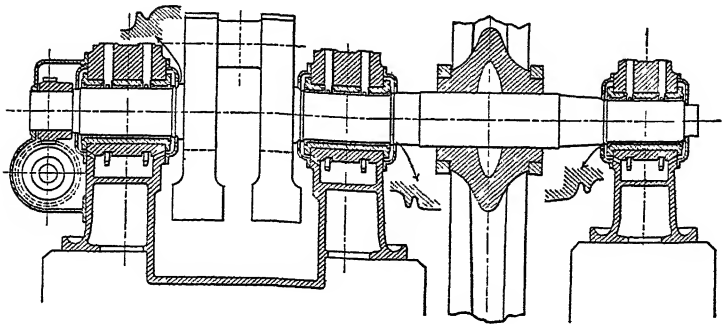


FIG. 139.—German shaft and bearings.

positions of the connecting rod. The sight-feed oil-cup at O, feeding both the piston and its pin.

Fig. 137 details the balanced crank-shaft, with a novel method for oiling the crank-pin, consisting of a disk with a cavity to receive the oil which is spread to the outer side by the centrifugal force of revolution and through the drilled passages to the crank-pin box.

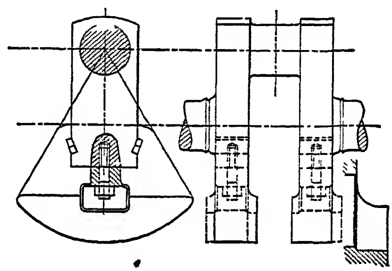


FIG. 140.—Fastenings of the crank counter-balance.

The proportions are to a scale in parts of the crank-pin diameter.

The base frame as usually made with flange-bolted cylinders is shown in Fig. 138, but its design is illustrated, with many varia-

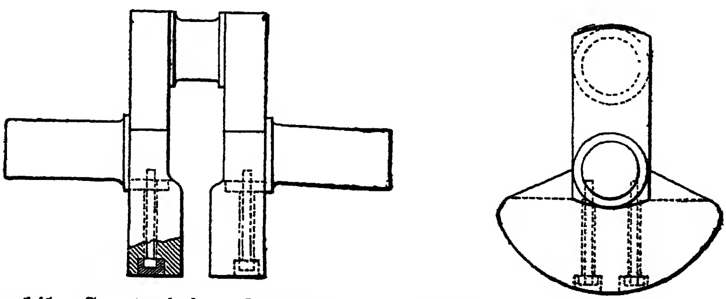


FIG. 141.—Counter-balanced crank, bolts or stud-bolts and nuts for each weight.

tions to suit special conditions, in the general views in the following pages.

In Fig. 139 is delineated the crank-shaft of the larger German motors with an outboard-bearing and enlarged shaft diameter for the safer keying of the fly-wheel. It will be seen that the left-hand end of the shaft has its size reduced to accommodate the desired small size of the spiral gear. All parts of this cut are made to a scale derived from the diameter of the main journal as a unit.

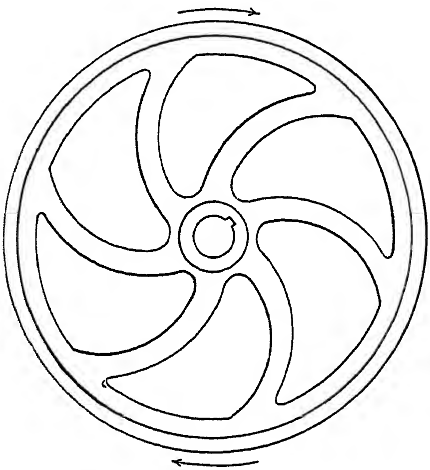


Fig. 142.—Fly-wheel of approved design.

It will be noticed that the shoulders of the journals are lipped in order to divert the excess of oil into the ring oil-reservoirs.

In Fig. 140 is shown the method of fastening the counterbalance to the crank by a short stud-bolt, with the nut in a mortise in the side of the counterbalance. The centrifugal strain is countered by the diagonal keys in the side-bearing.

Fig. 141 shows the ordinary method of fastening the counterbalance weights to the crank: a close fit and two strong tap-bolts or stud-bolts and nuts for each weight.

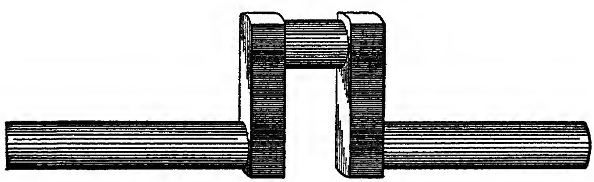


Fig. 143.—The plain single crank.

In Fig. 142 is shown the design of a fly-wheel of approved form. The curved side of the spokes should turn forward as shown by

the arrows, which produces compression of the spokes at the moment of impulse and thus avoids possibility of fracture.

This form is also safest in casting, as it avoids fracture by shrinkage. The models of straight-arm fly-wheels are illustrated further on ; for fly-wheel dimensions see Chapter X.

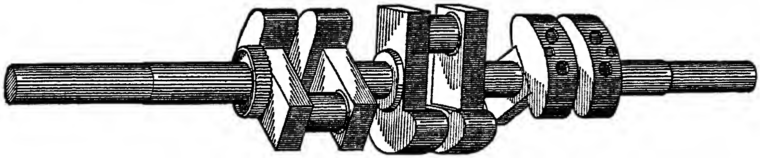


FIG. 144.—Westinghouse three-throw crank.

In Fig. 143 is shown the model of the plain single-crank shaft in general use.

In Fig. 144 is shown the three-throw crank-shaft of the Westinghouse Machine Company, with their method of balancing by screwing the balance-blocks to the crank-arms.

In Fig. 145 are represented a German type and horizontal housings, with the method of keying the crank-counterweight in addition to the usual stud-bolts and nuts.

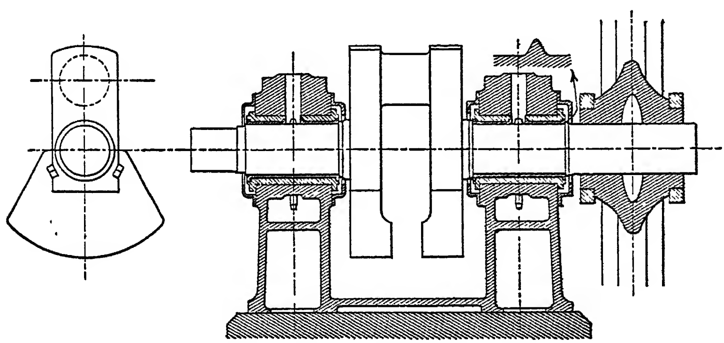


FIG. 145.—Crank-shaft and housings.

In Fig. 146 are llustrated a longitudinal and a cross section of a German journal-bearing with a double-ring self-oiler.

The cuts represent nearly the exact proportions, using the journal-shaft diameter as a unit.

In Fig. 147 is the sectional design of a single-ring oiling device of German design.

The pillow-block of an explosive motor is deserving of special

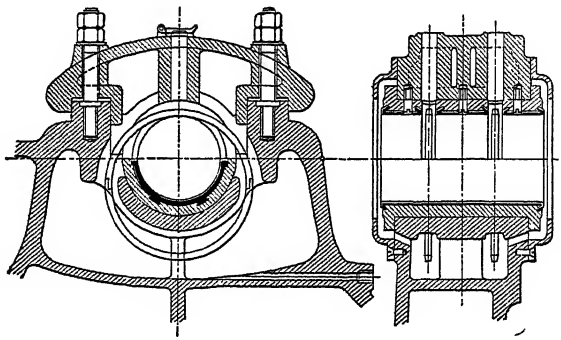


FIG. 146.—Horizontal self-oiling journal-box.

care in its design, in order to withstand the shock of explosion without injury to itself or the crank-shaft. A perfect journal fit will often save the breaking of a crank.

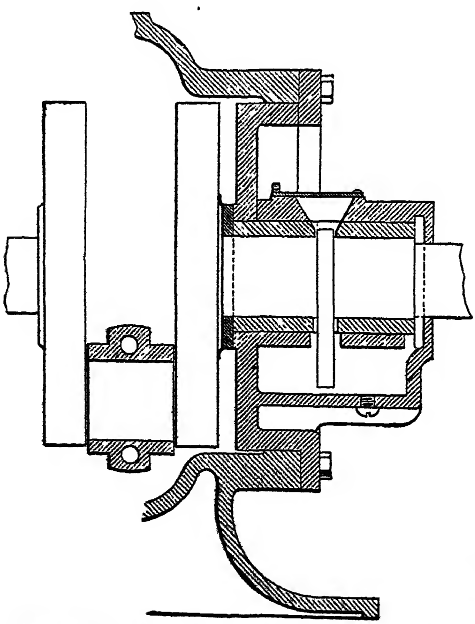


FIG. 147.—Single-ring self-oiling journal-box.

In Fig. 148 is detailed a half-section of a main journal-box of approved design. The composition box has a stop-rib to keep it from turning. The length of the journal-bearing should be twice the diameter of the crank-pin.

The proportions in the cut are a fair representation with the journal-shaft diameter as a unit. Also see illustrations of motor details further on.

We illustrate both the horizontal and angular style of journal-box housings, as both are in general use. It is claimed that the angular housing is the least complex and most reliable for strength and wear to sustain the one-direction shock of explosion.

One of the fine points in fitting the main journal-boxes for perfect work is to give the ends a perfect bearing, so that they may not sag at the inner end by the explosive blows and elasticity of the shaft, and thus extend the length of the shaft between its actual bearings; this condition being too often neglected, resulting in the mystery of a broken shaft.

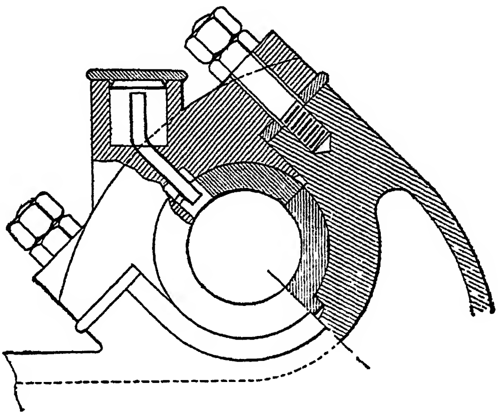


Fig 148.—Main journal-bearing.

Boring the housings and turning the bored boxes on the outside with keys to hold them in place is probably the best practice.

There is a difference of opinion among designers and builders of explosive motors in regard to the kind of metal or alloys for the journal-boxes, each advocating some special composition as the best: phosphor bronze, Tobin bronze, aluminum bronze, tin-copper bronze, and Babbitt metal being in use. For low-compression motors the phosphor and Tobin bronzes give good results. Babbitt metal is a cheap substitute in fitting; but the hard alloy is weak and liable to crack under the heavy blows of explosion, and the soft alloys are still weaker and liable to spread. For high-compression motors the ten per cent. alloy of aluminum and copper (aluminum bronze) and those of tin and copper are tough and resisting, wearing well. Probably there is nothing better than aluminum bronze for hard work..

CHAPTER XV

EXPLOSIVE-MOTOR DIMENSIONS

The diameter of the cylinder of an explosive motor and its initial pressure are the safest bases from which to compute the dimensions of all the parts subject to strain by the action of the motor.

As compression of the explosive charge has a greatly controlling influence on the initial explosive pressure, it should be made an exponent in every formula for strength against the strains of explosive pressure.

In a cylinder, as well as in other parts, the dimensions given in the formulas are for finished sizes; for cylinders, ample allowance should be made in the casting for boring.

Any simple proportion of diameter to thickness of cylinder wall, while giving the relative strain on different-sized cylinders, does not satisfy the practical condition of manufacture; which, to be safe and practicable on a basis of five times the extreme pressure, would be practically too thin for small cylinders and too thick for the larger size.

The tendency of constructive design at the present time is toward economy of material in general terms and the special requirement of lightness for marine and automobile service.

The strains on the various parts of a motor most to be considered are derived from the explosive moment, which are the pressures and strains due to the most intense part of the motor's work.

The ultimate or breaking resistance of the material of construction of the quality suitable for such work, is for cast iron suitable for cylinders—from 18,000 to 20,000 pounds per square inch, for which one-sixth, 3,000 pounds, is a safe factor or margin for computing the thickness of cylinder walls subject to an extreme pressure of 500 pounds per square inch. Then for obtaining the least safe thickness of cylinder wall, under the consideration of strength alone, the safe-resisting thickness will be derived from the extreme or maximum

pressure in pounds per square inch multiplied by one-half the diameter of the cylinder in inches.

$$P\times\frac{D}{2}=\text{stress, and }\frac{\text{stress}}{\text{factor of strength}}=\text{thickness in inches or}$$

decimals.

For example, a 10-inch cylinder and maximum pressure of 500 pounds with a safe factor of 3,000 pounds. $500\times\frac{10}{2}=2{,}500$, and $\frac{2{,}500}{3{,}000}=.833$ inch thick, to which should be added enough to meet the contingencies of unequal thickness in setting the core and for boring in the making of the pattern.

The next vital point from which trouble may arise, is the compression-strain on the piston-rod, boxes, pin, and crank-shaft at the moment of explosion.

The tortional strain on the crank-shaft does not reach its maximum effect until the piston pressure has fallen to one-half the initial pressure, and on this only depends the diameter of the main journals to resist torsion due to the fly-wheel resistance. The dimensions of these parts have been developed both theoretically and by practice, from which these formulas have been derived.

The author finds that the square root of the diameter in inches, divided by 5, $\frac{\sqrt{D}}{5}$, gives a much more satisfactory thickness of cylinder wall for low compression, say 40 pounds and under. For higher compression, say up to 100 pounds, a compression exponent should be added to the above formula, for which we propose $\frac{\sqrt{D}}{5}+\left(\frac{\sqrt{D}}{5}\times\frac{\text{comp.}}{250}\right)$ as giving a satisfactory safe thickness for high-compression cylinder walls at the clearance end of the cylinder. The crank end may be made thinner when the cylinder is supported by the jacket casting, or should have its thickness uniform when it is to be bolted to the frame with a flange.

By this formula a low-compression 4-inch cylinder wall may be .4 inches thick, and for high compression .56 inches. This gradation will give a 10-inch cylinder .63-inch and .87-inch wall, and for a

16-inch cylinder .89 and 1.27 inches respectively for low and high compression.

For the water space, the thickness is a matter of expertness in making cores that will stand the strain of moulding and casting; but on general principles the thickness of the water space should equal the thickness of the cylinder wall; except when the jacket is made in a separate piece, when the water space may be made to suit the convenience of construction.

The thickness of the water-jacket wall with a cored water space may be one-half the thickness of the cylinder wall, depending upon the method of fastening the cylinder to the bed-frame; whether flanged on the head or with side-flanges on the jacket.

These are matters of study, shown in the detail illustrations throughout this work.

The sizes of valve-aperture are a ratio of the volume and piston speed for the best effect and we find that the square root of the cylinder diameter in inches, multiplied by the piston speed in feet per minute, the product divided by 600 $-\frac{\sqrt{D}\,S}{600}=d$, gives a very satisfactory size for the inlet-valve aperture. The exhaust-valve should be one-fifth larger in diameter. This is suitable for motors at ordinary speeds, to have the valves fitted in the head of the cylinder; but for high-speed motors, up to 1,000 or more revolutions per minute, side-chambers may be made available for larger valves.

The form of valve seats, their angle and width, with the variations in practice, are fully shown by the detailed illustrations throughout this work, and in the section on valves and their design.

The dimension design of pistons varies considerably in European and American practice; but on general principles lightness, with due regard to resistance to the impact of explosion on the piston-head, and to lessen the balancing weight, is most desirable.

For pistons of 8 inches diameter and under, there need be no bracing ribs at the back of the head, while for larger sizes the ribs strengthen a comparatively thin head and increase the cooling effect from air circulation within the piston. For the cylindrical shells of all sizes up to 20 inches diameter, the thickness of the metal under the ring-grooves and beyond the pin-bosses may conform to

the formula $\frac{\sqrt{D}}{6}$ for shell-thickness and $\frac{\sqrt{D}}{4}$ for the heads. The pin-bosses should have a proportion for the strain on the forward side with a sub-boss for the set-screws. The number of rings varies somewhat among builders of motors; but good practice seems to indicate three rings on pistons up to 6 inches diameter and four to five on the larger diameters. A supplementary ring near the open end of the piston is not recommended as of any value.

The bearing length of piston-pins varies somewhat among builders in Europe and the United States from $1\frac{1}{4}$ to twice their diameter. One and a half diameters for the bearing length is a good proportion, and for this proportion the formula for the diameter may be $\sqrt{D} \times \frac{\text{comp.}}{150}$ makes a fair ratio for different cylinder-diameters in inches to meet the difference in extreme explosive pressures due to difference in compression.

The length of the connecting rod of an explosive motor varies from two to three times the length of the stroke; the longer rods being better adapted to the horizontal model.

The diameter of a round connecting rod should be at its largest part a slight swell from the crank end for one-third its length and with a gradual taper to the piston end, to four-fifths of the largest diameter. For the largest diameter the formula $\frac{\sqrt{D}}{2} \times \sqrt{\frac{\text{comp.}}{75}} = d$, gives a safe size for explosive pressure.

The crank-shaft requires much consideration from the great strain that it sustains at the moment of explosion, when the shaft and crank-pin are on the centre line and at that moment subject to the greatest strain. The strain is at first a bending one, changing to a tortional one as the crank angle increases. The basis of a formula is from the cube root of the square of the diameter multiplied by the compression and their product divided by 100 gives good proportions for steel shafts with strong fuel-pressure in inches of diameter. D = diameter of Cylinder. $\sqrt[\frac{2}{3}]{\frac{D \times \text{comp.}}{100}}$

The journals should be twice their diameter in length and the diameter of the crank-pin should be from 12 to 15 per cent. larger

than the main journals for equivalent strength to resist the initial blow of explosion. The width of the crank-arm should be 1.33 times the diameter of the crank-pin, and its thickness .7 the crank-pin diameter.

The form of the frame or engine-base is so varied among builders that we can only advise following the designs illustrated throughout this work, with a main view to a safe margin of strength due to the assumed pressures on the piston in the top member of the frame. The other parts to conform to lightness and constructive effect.

The method of counterbalancing the reciprocal and revolving parts of a motor, that contribute to its vibration is still a mooted point among designers of motor-motion, without arriving at a possible balance system for both motions.

As these conditions of reciprocating combined with circular motion cannot be made to agree, a mean equalization of the two forces seems the only possible solution.

The following formula for the weight of a counterbalance of the form in Fig. 141, bolted to the crank, is an approximation for equalizing the reciprocating and revolving parts $\frac{P+C}{2} \times \frac{R}{r} = W$, in which P = weight of piston and rod; C, weight of crank and $\frac{1}{3}$ of rod, crank-end weight; R, radius of crank in inches; r, radius of centre of gravity of counterweight.

The fly-wheel of an explosive motor is a matter of much consideration in regard to its weight and diameter for the many conditions for its application to the speed-control of the motor-impulse. On general principles, a four-cycle motor requires more fly-wheel control than the two-cycle type. A single cylinder of either type more than motors of two, three, or four cylinders.

Again, slow-speed motors of any type or number of cylinders require more fly-wheel control than high-speed motors. A high-compression motor more than one of low compression; so that the problem becomes a complex one in order to exactly meet every condition of motor service for stationary, marine, and vehicle propulsion.

For stationary power, a fly-wheel diameter of four times the stroke of the piston is the usual practice. For marine and automobile service the fly-wheel diameter should be much smaller to meet

the conditions of boat and vehicle construction with their weight increased to the motor requirement.

The formula $\frac{\text{I. H. P.}}{\text{rev. pr M}} \times 34{,}000$ gives a good average weight of the fly-wheel rim for diameters of four times the piston-stroke.

The diameter of a fly-wheel hub should be $2\frac{1}{2}$ times the diameter of the shaft; the spoke-web, $3\frac{1}{2}$ times shaft diameter. The spokes should taper slightly from web to rim, and each have a mean area of $\frac{2}{3}$ the shaft area at the web. A study of details illustrated in this work will suggest the best forms of rims and other parts from the practice of builders.

WORM-GEAR

The reducing gear of the worm-gear type may be made an exact relation for difference of speed, which for the four cycle explosive-motor valve gear should be two revolutions of the crank-shaft to one revolution of the valve-shaft. As the relative pitch diameters of the gears cannot always be made the same, some fixed relative diameter must be made and the spiral angle of their teeth cut to meet the required speed relation; or with a fixed angle of the teeth, the pitch diameters must be made to meet the required speed relation. Thus if the spiral angles of two matched gears are the same the velocity ratio will be inversely as the pitch diameters; but if the spiral angles are not equal, as in the usual gas-engine gears, the number of teeth per inch of pitch diameter will vary as the cosine of their angles. In any case the velocity ratio will depend upon the number of teeth and their spiral angle, as expressed in the following proportion: v, the velocity of the small gear, is to V, the velocity of the large gear, as D, the pitch diameter of the larger, multiplied by the cosine of its spiral angle, is to d, the pitch diameter of the smaller, multiplied by the cosine of its spiral angle.

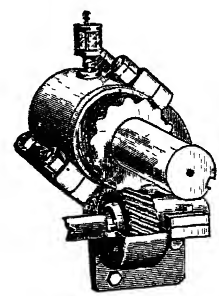


FIG. 149.—The worm-gear.

Then, for example, a shaft spiral gear of twice the pitch diameter of the cam-shaft gear and running at twice its speed, their rel-

ative teeth spiral angles will be $2 \times 2 = 4$, and for the proper meshing of their teeth, requires that any $\frac{\text{cosine}}{4}$ that will equal its sine, will represent the proper angle of the teeth of the driving gear with the plane of its motion; while the angle of the driven gear-teeth will be the cosine of the plane of motion of the driven gear. By comparison of sines and cosines as tabulated, we find that a $\frac{\text{cosine}}{4}$ is equal to the sine of 14° 2′, and the cosine 75° 58′, which represents the relative angles of the teeth of the driver and driven gear with their planes of motion in the above case.

For spiral gears of equal diameter for velocities of 2 to 1 to match, with the shafts at right angles, the engine-shaft gear should have the lesser angle and the gear on the reducing or secondary shaft should have the greater angle as referred to their planes of motion respectively. The cosines of these angles must bear the same relation to each other on the pitch line as their velocities, and by inspection of a table of sines and cosines this relation is easily found; for example, in following along the columns of sines and cosines we find .44724 is as 2 to 1 to .89448, which agrees nearly to 26° 34′ and 63° 26′, the respective angles of the teeth with their planes of motion for equal-sized gears; their sum being equal to 90°.

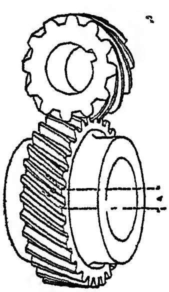


Fig. 150.—Spiral or worm gear.

VALVES AND THEIR DESIGN

The general designs of explosive motors, so far as their power moving parts are concerned, are so much alike that, excepting their ignition devices, any explosive motor may be made interchangeable or readily convertible to the use of either of the explosive materials for power, for each requires an equal strength in all the parts of the motor as well as an equal treatment in the regulation of cylinder temperature.

The value of the materials of explosive power has been as fully discussed under the head of "materials of power" as is con-

sistent with our present knowledge of the experimental details in regard to the explosive values of such materials. Their study becomes an essential feature in motor design, especially in regard to cylinder volume to meet specified power.

The details of valve gear may be made variable to meet the fancy of designers or their judgment of fitness; but there are a

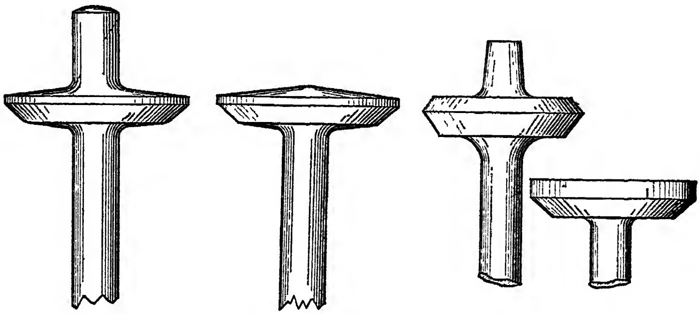


FIG. 151.—Steel drop-forgings.

few points in their operating principle which must be made to meet the requirements not only of each form of explosive element to be used, but also of the varied values of gases in gas-engines, from acetylene to producer and blast-furnace gas, and of the volatility of the variable grades of gasoline, kerosene, and the cruder oils, and which dominate the sizes and relative proportions of the inlet and exhaust-valves.

The forms of the faces and seats of valves seem to have been varied to meet the fancy of designers in a great measure, and even the crudity of a spindle riveted to the valve disk has been used and published as a desirable makeshift. The flat-faced valve is also in use, but from the author's experience is unreliable and makes an imperfect seat by use. Conical-seated valves with faces at from thirty-five to forty-five degrees from the axis of the spindle are giving good service. A flatter cone of from fifty to sixty degrees is in use with apparent wearable properties and with slightly less lift for its full area than with the deeper-seated valves. A fifty-degree angle is recommended for high-speed motors.

Spindle-valves with stems one-fifth to one-quarter the outside diameter of the valves, well filleted under the disks, give general

satisfaction for ordinary speeds; but for very high-speed motors the valve stems should be somewhat larger. The general valve arrangements are well shown in their various modifications as illustrated in this work.

The relative size of these valves has been a subject of inquiry and discussion, with so far no fixed general rule applicable to the required conditions of each element. Some designated speed should first be assigned for any given-sized cylinder volume, from which the size of the valves may be computed for the full flow of the inlet charge and for the discharge of the exhaust without undue back-pressure during the times of the inlet and exhaust-strokes. This means larger valves for high-speed than for low-speed motors—a practice too often ignored, to the detriment of motor efficiency, by making these valves too small for the motor's best work; while if made to meet the requirements for highest speed capacity their efficiency action will be best for all lower speeds. This should be made a study with the designers of explosive motors.

The present practice with builders in regard to the size of the valves seems to vary the extreme diameter of the exhaust-valve from a quarter to four-tenths of the diameter of the cylinder, and the charging valve a little less, sometimes but one-fifth of the diameter of the cylinder.

Indicator cards taken from motors with small valves, if properly done, plainly show the effect of back-pressure from both the exhaust and charging strokes. Good practice suggests the larger valves with full lift of one-quarter their diameter for developing the full power of the motor.

The width of the valve contact-seat has been the cause of much trouble with valve action by the mistaken judgment of designers—that great width of contact adds to tightness and wear of the valve and seat. Practically this is an error that should only be tolerated with inlet-valves having fuel feed through holes or channels in the seats. The width of bearing on inlet and exhaust-valves should have no more than one-eighth of their diameter.

The conical bearings should also be the limit of inside and outside diameter for valve and seat.

The best material from experience is solid valves of mild cast

steel, "machinery-steel" grade; of which the drop-forgings (Fig. 151) are good examples; the tips to be cut off in finishing.

There are differences of opinion in regard to the methods of opening the inlet-valve, the "suction or vacuum," and the "mechanical-lift," of which both are in use, the principal difference visible turning on the point of simplicity and complexibility in valve-gear construction. Theory, as well as practice, places the percentage of efficiency in favor of the "mechanical-lift."

With the suction-lift the piston must travel a certain distance in the cylinder to create a vacuum strong enough to act upon the surface of the valve to lift it, and overcome the tension of the light spring that is acting against it to cause it to return to its seat quickly. The tendency of the suction-valve is always to return and remain on its seat, and it is only opposed from doing so as long as the vacuum in the cylinder is strong enough to hold it therefrom. Thus the valve chatters as it remains in space trying to respond to the summons of both agencies, the spring and the vacuum. While so doing it retards the inflow of mixture to the cylinder. If the spring has too great a tension the vacuum cannot properly lift it, and the cylinder is deprived of a sufficient amount of mixture. If the tension is too weak then the valve does not seat quickly enough, and part of the charge drawn in is forced back again through the inlet until the valve has made a proper seating, with the possibility of back-fire. Thus can be seen the value of a spring possessing the proper tension. Another thing that can be looked for is that a spring, when new and possessing the proper tension, will, in the course of constant use, lose some of its tension and change the results. The mechanically operated valve possesses a superiority over the suction type in several ways, and the additional expense and complication of operating an intake-valve is not worthy of mention. With a mechanically operated valve the necessity of having the spring tension to a certain point is obviated. But the spring should be strong enough in tension so as to always ride the cam that lifts it, but not too strong, to make working on the mechanical parts too severe. A motor with a mechanically operated valve will start more easily and is more sure of starting than the suction-lift, for the simple reason that the cam, being timed properly, will open the valve immediately as the piston starts on its suction-stroke and

the vacuum immediately acts on the vapor without any extra duty to perform or obstructions in the way to give free access to a full and uniform charge.

ROTARY VALVES FOR EXPLOSIVE MOTORS

The slide-valve having passed its trial in the early form of the explosive motor, yielded its place from its mechanical defects and the progressive change in the manner of ignition to the poppet type. The flame ignition having been entirely superseded by the hot-tube and electric ignition, has left the valve question to be solved upon its merits alone. A sliding or rotating valve seems to work well in a steam-engine, where the steam is in part a lubricator and clean from grit or abrading material; but the sliding principle seems to have failed in fulfilling expectation and it is to be seen whether the rotary valve will survive its initial trials.

A balanced rotary valve has been lately brought into use by Mr. Edward Butler, of Gleneldon Road, London, England, which controls both the induction and exhaust, and so arranged in the design as to control two or three cylinders and has been applied with success to a 700-horse-power double-acting gas-engine; a 35-horse-power single-acting; a three-cylinder engine with a single valve and a tricycle. The valve is water-cooled by a jacket and in the double-acting engine the piston is cooled by water circulation through the piston-rods; the stuffing-boxes being also water-jacketed.

We await the success of the continued trial of the rotary valve.

MOTOR-CYCLES

The cyclical succession of operations, crank angles, and piston positions for the crank angle of each phase of the action of a four-cycle motor is shown in Fig. 152.

Commencing with the inner circle, it will be seen that the charging may commence just before the crank reaches the dead centre owing to the momentum of the exhaust just before the piston stops; resulting in an extension of the charging to a point beyond the outward dead centre. The momentum of the charge through the inlet-valve and the compression through the balance of the return-stroke are shown on the diagram; then ignition at any designated point

just before, at, or just after the dead point of the stroke. The explosive impulse in the outward stroke to a designated point for the exhaust-valve to open and exhausting to near the end of the return-stroke at which point the exhaust-valve closes by its spring pressure, just before the crank reaches the dead centre, are also shown in the outer circle.

The crank should move in the direction of the arrow and by withholding the closure of the exhaust-valve mechanically, a scavenging effect may be had by the momentum of the exhaust in its pipe-passage.

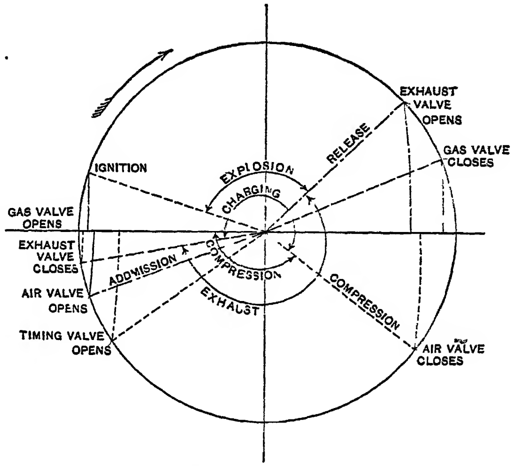


FIG. 152 —Cyclic phases of a 4-cycle motor.

The diagram is an example that may be changed to suit any required conditions, so as to show at a glance the piston positions and relative crank angles.

CAM DESIGN

The designing of explosive-motor cams, by many considered a difficult problem, can be worked out on the drawing-board with accuracy when the conditions of opening and closing time are given: For an exhaust-valve cam for a high-speed motor, assuming to open at 40° crank motion above the terminal of the impulse-stroke and closing at 10° past the rear centre, as shown in the motion diagram (Fig. 152).

Thus the valve is held open through 230° of the crank's revolution and therefore through 115° of the cam-shaft's revolution. The cam proper is made up of two parts—one portion, B M A (Fig. 154), concentric, and another portion, G E K, eccentric to the shaft. For convenience we will consider the cam to be standing still and

the cam-roller to travel around the cam-counter clockwise—i. e., from A toward B.

From centre O, lay off a circle A B M equal in diameter to the concentric portion of the cam. Then from O lay off O A and O B 115° apart. O A is the line on which the valve begins to open, and O B the line on which it is just closed. Lay off C D equal to the amount allowed for lost motion before the valve begins to open, and D E equal to the amount of the opening of the valve. With the centre O draw arcs of circles through D and E, respectively; E will be on the outer extremity of the cam. On O A and O B, pro-

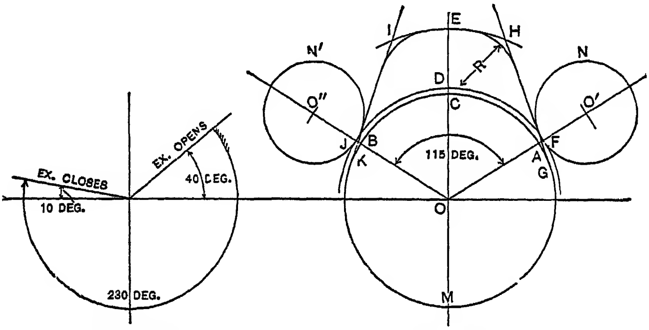


Fig. 153. Fig. 154.

Exhaust-cam design.

duced, lay off circles O′ F N and O″ J N′ equal in diameter to the cam-roller and tangent to the arc F D J. Draw G H tangent to both circles A B M and O′ F N; similarly K I tangent to both A B M and O″ J N′. This gives us the bounding lines of the eccentric portion, G E K, of the cam. The corners at H and I should be rounded off with radius R to suit the judgment of the designer.

For medium-speed motors the crank-angle opening of the exhaust may be made much less than the extreme figures above named and so varied for assumed speeds to as low as 25° crank-angle opening and 5° for closing.

These angles are also applicable where piston-ports are used.

A similar method applies to the inlet-cam as well, although the angle of opening is somewhat less than that of the exhaust-cam.

CHAPTER XVI

TYPES AND DETAILS OF THE EXPLOSIVE MOTOR

THE leading features of two-cycle engines are essentially an embodiment of the Day model as first made in England, and noted for the absence of valves for inlet and exhaust, and for a compression initial charge from a closed crank chamber, made by the impulse-stroke of the piston and a final compression and explosion of the charge at every revolution of the crank-shaft. The air and gas or

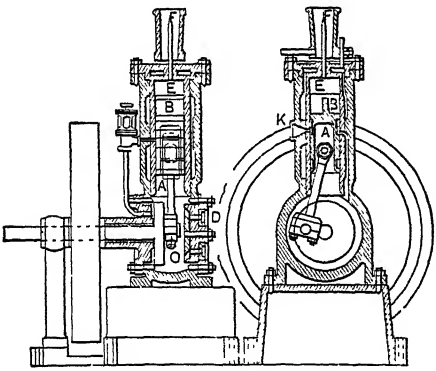


FIG. 155.—The Day model.

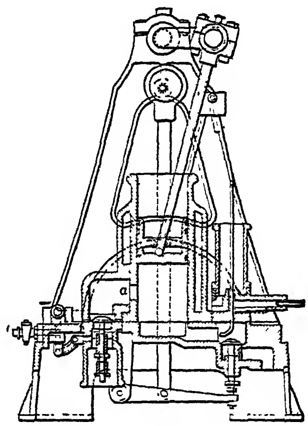


FIG. 156.—Root engine.

vapor are drawn into the crank chamber by the action of the piston and the mixture completed by the motion of the crank. From the absence of cylinder-valves and valve gear this type of explosive engine has the peculiar advantage that it can be run in either direction by merely starting it in the direction required. This type of motors receives its charge and exhaust through cylinder-ports at the end of the impulse-stroke of the piston. In some modifications of the Day model a supplementary exhaust is provided for by the use of a

valve in the cylinder-head or near it, which facilitates the passage of the fresh charge to meet the ignition-tube or electrodes, and thus contributes to the regularity of ignition.

This has become a leading type with many variations of detail, which are illustrated and described in the following pages of this work.

Among the many designs for increasing the power of a gas-engine the Root model for a duplex explosion seemed to be a step in the right direction. It is a four-cycle compression type with a secondary explosion chamber and cylinder-port, which is closed by the piston at about half compression stroke and shutting off part of the explosive mixture, which is exploded at about one-third of the impulse-stroke by the heat of the primary explosion in the clearance space at the beginning of the stroke. The gas and air mixture was injected through the supplementary chamber, thus leaving a strong charge for the secondary explosion, and so largely increasing the pressure during expansion of the exploded charge.

This type has not proved of practical value and the author knows of none in use in the United States. It was an English invention.

The non-vibrating gasoline-motor (Fig. 157) is of French origin, but now adopted with modifications by a number of motor-carriage builders, for its quiet running. It is of the four-cycle type with the cylinders offset enough to allow of a double crank at 180°. The ignition adjusted to take place at the same instant, thus almost entirely eliminating vibration, or ignition may be made alternately with a two-cycle effect. The radial ribs on the motors of suitable size for light vehicles are found efficient and most convenient in eliminating one of the troubles of explosive-motor power—the water-jacket. The Crest Manufacturing Company, Cambridge, Mass., are building motors similar to this type.

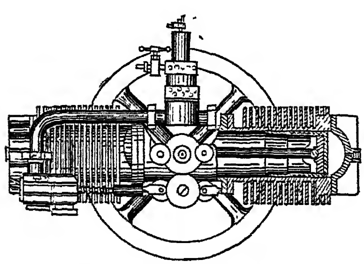


FIG. 157.—Non-vibrating motor.

Water-jacketed motors of this type for all uses are made by the

Brennan Motor Company, Syracuse, N. Y., a detailed section of which is shown in Fig. 158, which represents their four-cycle, high-compression, non-vibrating, opposed-cylinder motor, with a legend of its parts.

In Fig. 159 are illustrated some details of the Winton automobile-motor to which is given the names of the parts figured in the

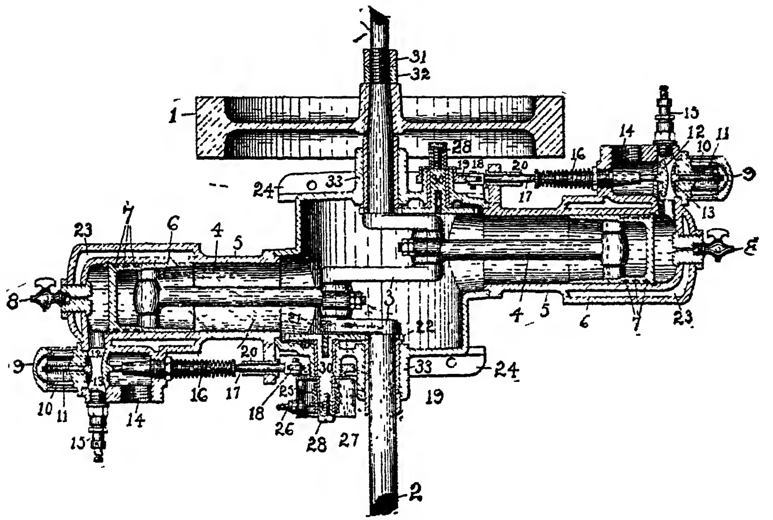


FIG. 158.—Sectional plan of the Brennan motor.

3 The crank-shaft. 4. Connecting rod 6 Piston. 7. Compression rings. 8. Relief-valve. 9. Cap for admission-valve case 10 Admission-valve case 11. Admission-valve spring. 12. Exhaust-valve. 13. Admission-valve 14 Exhaust-outlet. 15 Spark plug 16. Exhaust-valve guide 17. Push-rod 18. Push-rod roller. 19. Exhaust-valve cam 20. Sleeve for push-rod 21. Gear of secondary shaft 22 Gear on crank-shaft. 23. Water-jacket space. 24. Crank-pit and base. 25 Time-ignition case. 26. Post for battery wire. 27. Time-ignition cam. 28. Binding screw 30. Bearing for shaft. 33 Bearing for crank-shaft.

cut. The design is of a very compact and quick action. The detachable portion of the crank-case 48 is shown set off, to which is attached the hand hole cover and yoke.

A compact horizontal gasoline-motor, rib-jacketed, and designed for an automobile (Fig. 160), is of French origin. It has a special combustion chamber and attached valve chamber for facilitating ignition by tube or spark, the tube being shown in the sketch. P is a short platinum tube directly over the Bunsen burner G, operated by gasoline-vapor generated in the burner. H is the carbureter, which receives its charge through an automatic valve

where it is vaporized by warm air from over the burner. The vapor charge with its air mixture is drawn in through the valve E. A

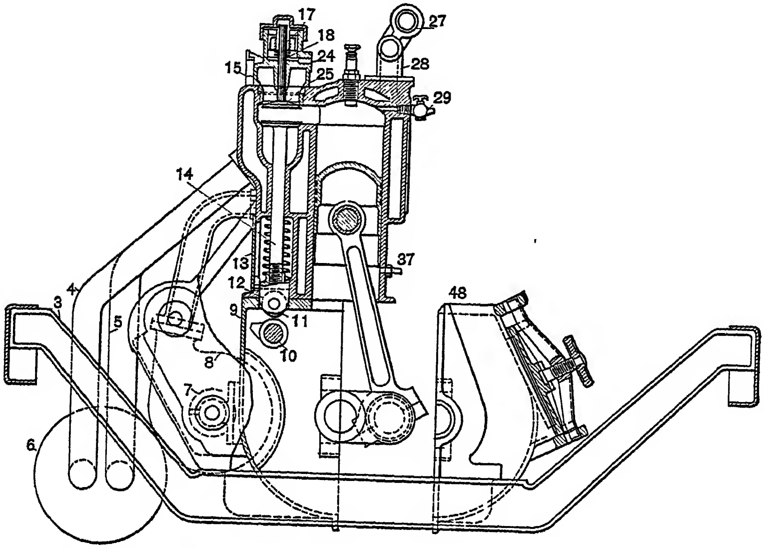


FIG. 159.—Section and frame of the Winton automobile motor.

Reference Numbers.—3. Drop-frame. 4, 5. Exhaust-pipe leading to 6 Expansion chamber or muffler. 7, 8. Water-circulating centrifugal pump. 9. Crank-case. 10. Exhaust-valve cam on secondary shaft for each cylinder. 11. Cam-roller. 12. Exhaust-roller guide. 13. Exhaust-spring chamber cover plate. 14. Exhaust-valve spring and spindle. 15. Inlet-valve chamber. 17, 18. Inlet-valve piston and spring. 24, 25. Inlet-valve chamber and valve 27. Bushings for spark-plug wires. 28 Water-pipe from cylinders to radiator. 29. Cylinder relief-cock. 37. Cylinder oil-connection. 48. Detached portion of crank-case.

reducing gear, cam and lever, operates the exhaust-valve, and speed is regulated by varying the charge of gasoline-vapor, which is controlled by an index-cock. The crank end and fly-wheel are enclosed

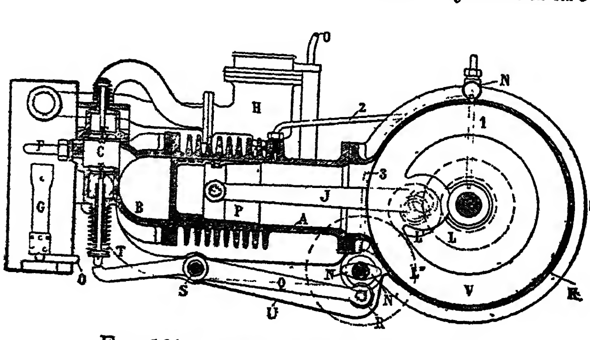


FIG. 160.—Gasoline automobile motor.

in a light iron case, which holds the oil for lubricating the journals and gearing. The other lettered parts are self-explanatory.

In Fig. 161 is illustrated in section a two-cylinder marine automobile-motor of European design, with platinum hot-tube igniter. The gasoline is fed through a regulator to a jet-nozzle at the bottom of the atomizing chamber K and mixed with the incoming air

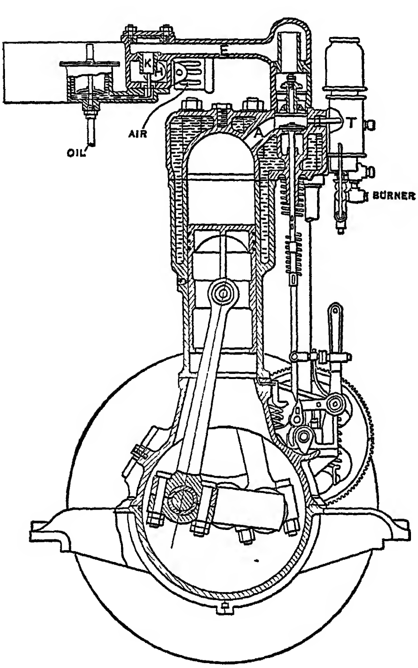


FIG. 161.—Vertical marine or automobile model.

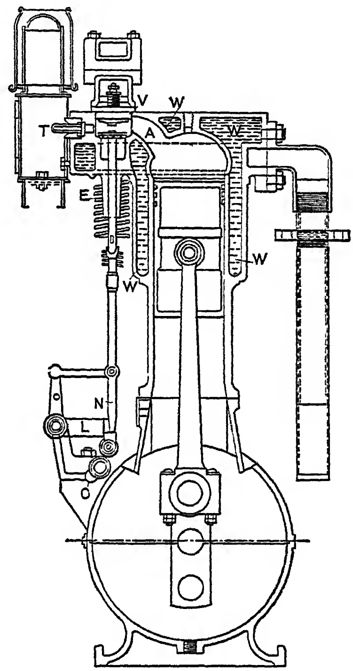


FIG. 162.—Vertical stationary model.

through the cage and air chamber H, and finally vaporized in the passage E.

In Fig. 162 is illustrated a vertical stationary model, also of European design, and also with a platinum hot-tube igniter and similar feed as described above. The cylinder-heads of both motors are water-jacketed, integral with the cylinder. The exhaust-valves of both motors are operated by a pick-blade action from cams on the secondary shafts; but by what means the speed is governed is not made clear.

In Fig. 163 is illustrated a vertical motor of European design with cross-head and guides, in section, and in Fig. 164 a side-view

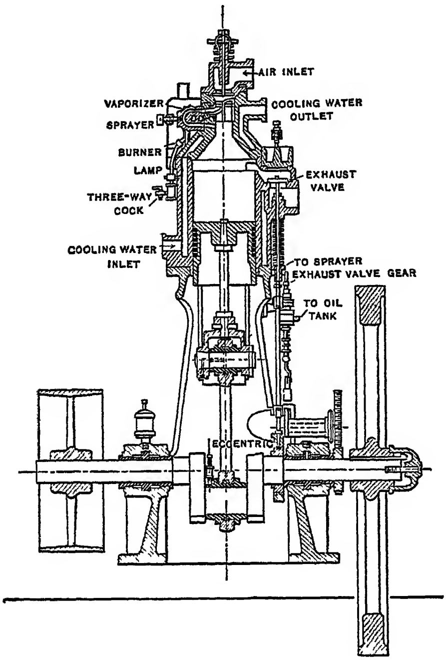


FIG. 163.—Sectional elevation.

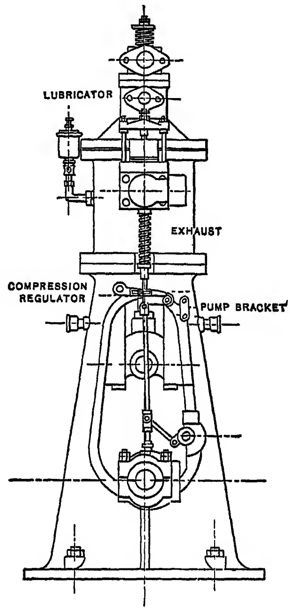


FIG. 164.—Side view.

of the same motor. This type relieves the piston of side-thrust, but involves a longer gait or shorter connecting rod; a disadvantage

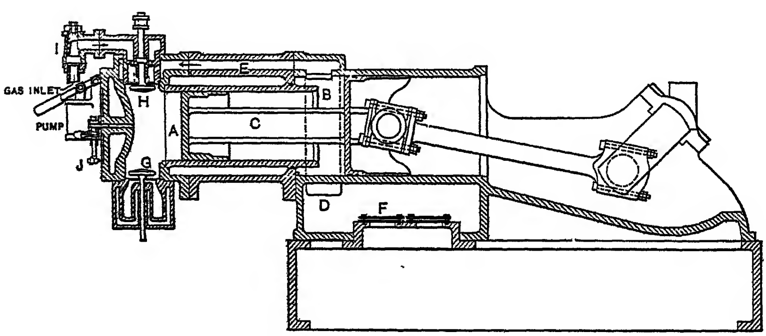


FIG. 165.—Differential piston-motor.

not approved of by our best engineers. It is derived from the lean of designers toward steam-engine practice. It is a departure from the most approved explosive-motor practice and is not recommended as the basis of simplicity in motor design.

In Fig. 165 is illustrated a gas-engine of the scavenging class, of European design, in which a piston of larger size than the engine-piston acts as a cross-head for the connecting rod and as a pump for compressing the air-charges. Each outward stroke of the differential pistons draws air through the valves F, and by the return strokes compresses it in the chamber D, which communicates with the passage E, for furnishing the charge under pressure. The inlet-

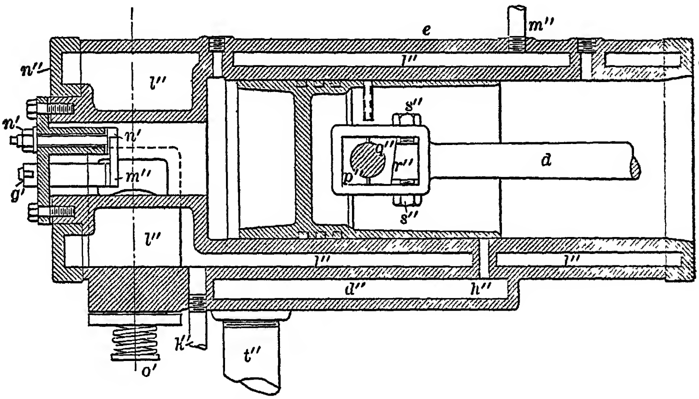


FIG. 166.—Vertical section of cylinder.

valve H opens during the last moment of the exhaust-stroke, forcing a scavenging blast from the accumulated pressure in the passage E. The double piston largely adds to engine friction and complication, which lessens the mechanical efficiency to a greater extent than the value of the scavenging effect.

In Fig. 166 is illustrated a vertical section of the gas and gasoline-engine as built by the Columbus Machine Company, Columbus, O. Its design has been toward the fewest parts that will give efficiency, ready adjustment, and renewal of vital wearing parts, together with a gas and gasoline attachment that allows of interchange of fuel elements without stopping the engine, if necessary.

It has a supplementary exhaust through a port in the cylinder,

opened by the piston at the end of its stroke, which has been shown to be a great relief to the work and wear of the exhaust-valve, as by this exhaust arrangement the exhaust-valve opening follows the piston-port opening.

The governor controls the gas and air charge by holding or throttling the inlet duplex-valve, the lower section around the spindle being a gas chamber fed by the pipe *y* (Fig. 167), while the annular chamber receives the air through a side inlet, the mixture taking place between the two valves. The spindle of the gas-valve is hollow, through which the spindle of the inlet-valve passes beyond the spring-block *x*, at *o′*, so that the cam-operated lever opens the inlet-valve first and wider than the gas-valve. Both valves are fitted and seated in removable cases; the cylinder and head being cast in a single piece. The hole through the cylinder-head serves the work of boring the cylinder, and to receive the igniter device, which is a contact-break with a wiping motion, which prevents fouling of the electrodes, as shown at *m′*, *n′*.

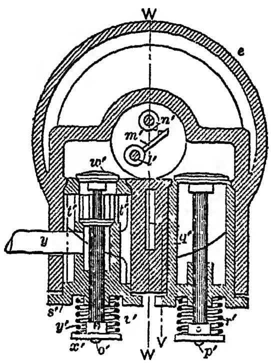


FIG. 167.—Valve-cases.

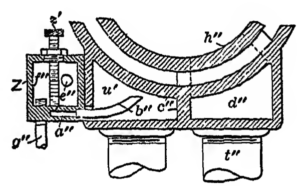


FIG. 168.—Gasoline attachment.

In Fig. 168 is a section of the gasoline attachment, consisting of a constant-level chamber *f″*, an inlet-pipe *g″*, overflow exit *e″*, a small needle-valve *z′*, and tubes *b″*, discharging into the air-mixing chamber *u′*. The cylinder and its water-jacket is cast in one piece with an open water space at the crank end, which is covered with ring flanges *o″* and *n″*. The ignition and valve chamber are water cooled as shown at *t″*.

In Fig. 169 is shown a sectional plan of the White and Middleton motor of the four-cycle compression type, with the principal exhaust-

port opened by the piston at the end of its impulse-stroke. The supplementary exhaust-valve is operated by a lever across the cylinder-head and a push-rod direct from a differential-slide mechanism, which does away with the reducing gear used on other engines. An arm on the push-rod operates the gas-valve stem, which is provided with a regulating adjustment.

A small roller-disk on the push-rod mechanism is under the control of a centrifugal governor and a spring, being thrown out of gear with the shaft-cam whenever the speed of the engine exceeds the normal rate, and thus failing to open the gas supply and the supplementary exhaust-valve until the speed of the engine has returned to its normal rate. There is a relief-valve opening into the supple-

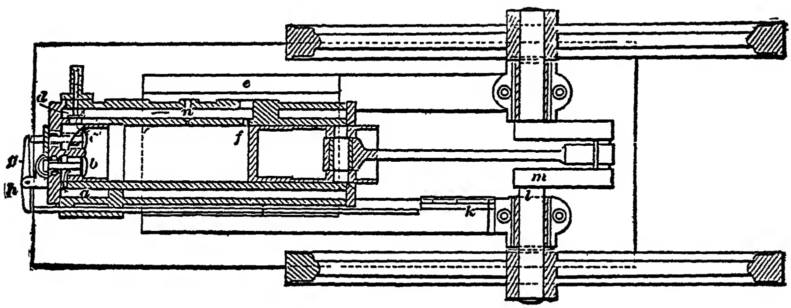


FIG. 169.—Sectional plan of the White and Middleton engine

mentary exhaust-passage for relieving the pressure in the cylinder when starting the engine. The whole design of the engine is exceedingly simple and its action noiseless.

When gasoline is used the gas-supply valve is replaced by a small pump, which is operated by the push-rod, and its hit-or-miss stroke is governed by the action of the push-rod and its governor.

We illustrate the special construction of the Lewis gas and gasoline-motor in Figs. 170 and 171, built by J. Thompson and Sons Manufacturing Company, Beloit, Wis. The principal feature of this motor is the addition of the cylinder-port exhaust as an auxiliary to the regular exhaust-valve, which is now a conceded measure of economy in reduced exhaust back-pressure and in the saving of wear on the exhaust-valve.

The vaporizer is shown in section in Fig. 171, which consists of a chamber M, with an air-pipe A, by which the mixture of gasoline and air is regulated by drawing the air-pipe to or from the surface of the gasoline constant-level, which is regulated by the overflow-pipe at M. A further regulation of the charge mixture is made by the valve at the right of the vaporizing chamber. The gasoline-pump is operated from the arm of the exhaust-valve lever. The igniter is of the hammer-break type and is attached by a flange to the side of the inlet chamber and operated directly from a snap-cam on the reducing shaft. The governor limits the lift of the inlet-valve through the arm on its spindle.

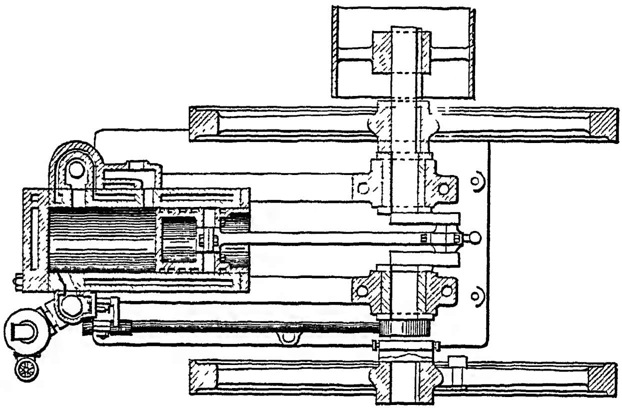


FIG. 170.—Lewis motor.

In Fig. 172 is shown a sectional plan of the Olin gasoline-engine. It is of the four-cycle type with an exhaust-port opened by the piston at the end of its impulse-stroke by which the exhaust with its terminal-stroke heat is impinged upon a tube through which the charge is fed and vaporizes the gasoline. The exhaust surrounds the vaporizing tube by the passage and chamber J. The exhaust is continued after the closure of the piston-port by an annular valve around the inlet-valve.

In Fig. 173 is shown the sectional detail of a vehicle motor lately brought out in France. The engraving has been made on a scale of $\frac{3}{16}$ of an inch to one inch, the diameter of the cylinder being $3\frac{7}{8}$ of an inch, with 4-inch stroke. It is rated at 4 horse-power at full speed.

A novel arrangement for cooling the motor by means of a mechanical ventilator has been adopted, and is one of the most successful features of this motor. Motors with the ordinary type of cooling wings, of which the De Dion is a good example, offer great advantages of simplicity which make them preferred for the smaller powers, but unfortunately they do not always give entire satisfaction on account of the insufficient cooling when the vehicle moves slowly and the current of air is small; this is especially noticed in hill-climbing. To remedy this the motor runs a small fan which is mounted on ball-bearings and consequently

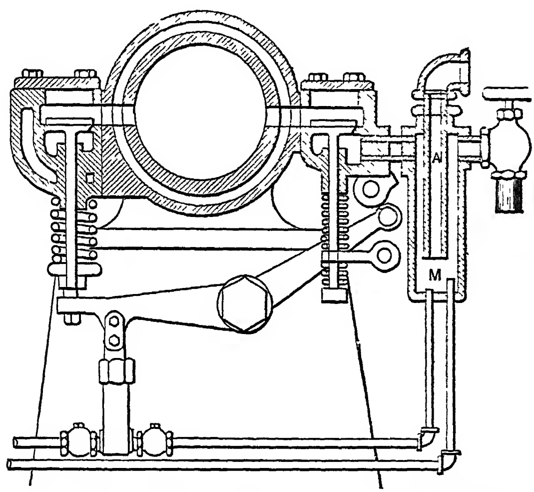


FIG. 171.—Vertical section of motor and vaporizer.

takes but little power. It is set in motion by a friction-roller in contact with the fly-wheel of the motor. This ventilator blows a current of air against the motor-cylinder, and thus the cooling is independent of the speed of the vehicle. This motor drives by a shifting belt on tight and loose pulleys with separate speed and reversing gear. It is noticed that the crank-shaft bearing is six times longer than its diameter, which makes the balanced crank self-supporting, the pin of which carries freely a secondary gear-crank 45 and pinion, gearing into a spur-wheel on the cam-shaft 46, which also operates the electric-current brake (37–39) with a jump-spark igniter 26. Oil is·fed at the bottom of the cylinder

into an annular groove into which the lower edge of the piston dips at each stroke. The main journal is oiled by the overflow from the annular groove and the dash of the crank, through the long oil-passages and the surplus returned to the crank chamber from the end of the bearing. A leather washer between the end of the shaft bearing and the fly-wheel hub prevents waste of oil and entrance of dust. Speed is controlled by the gasoline-feed through atomizing vaporizers (which see, ante). This class of motors makes an excellent study for amatuer mechanics.

The latest design of the Nash gas-motor is illustrated in section in Fig. 174. It is of the four-cycle type, with one, two, or three vertical cylinders. The speed is controlled through the governor by missed charges.

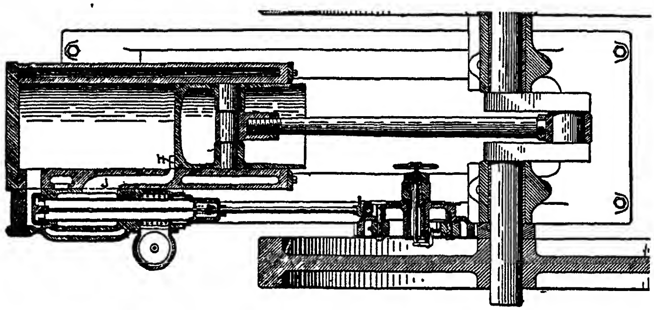


FIG. 172.—Plan of the Olin gasoline-engine.

The air chest surrounds the passage by which gas enters and is drawn with the air into the mixing chamber A. The admission valve B is open during each suction-stroke and the mixture passes through that valve to the cylinder to be compressed upon the succeeding stroke and then exploded. The toe which lifts the gas-valve is carried upon the stem of the admission-valve and is kept from engaging with the latch upon the gas-valve stem when explosion is not required. The admission is operated by a positive cam upon the side-shaft in an obvious manner, and the fact that it is opened every fourth stroke insures an indraft of fresh air, even when no gas is admitted, scavenging the cylinder of any products of combustion remaining. The exhaust-valve is similar to the admission-valve, but its roller can be thrown to a cam, relieving the compression when starting up. The igniter is at 1 and is oper-

ated by an eccentric upon a side-shaft on the opposite side of the engine, this side-shaft being operated by a cross-shaft geared to

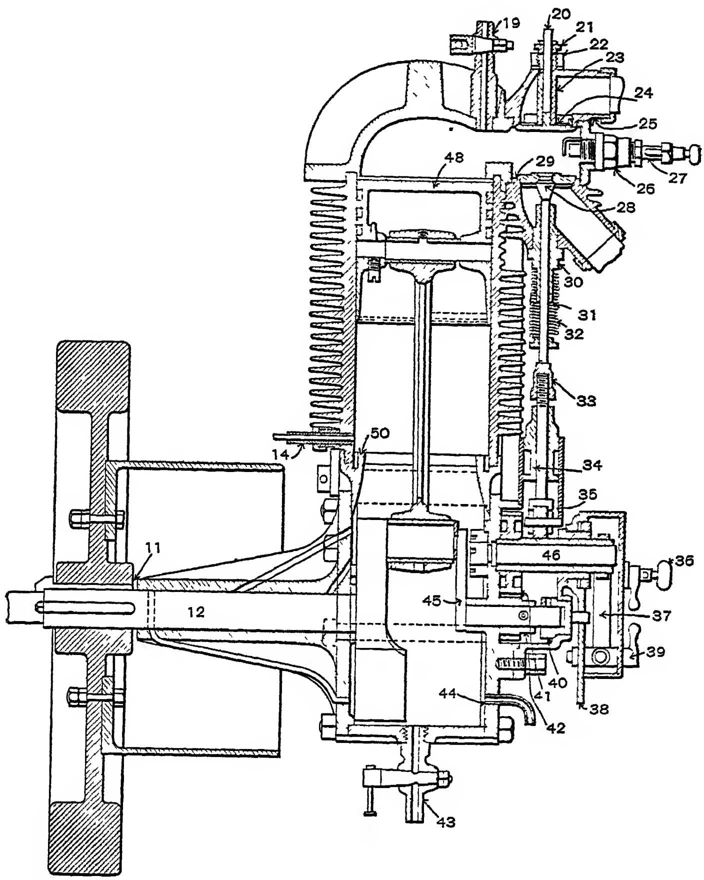


Fig. 173.—Section of air-cooled motor.

Figured parts of the motor.—12. Crank-shaft. 13. Oil-cooling tube. 14. Oil-duct. 19. Pet-cock. 20. Key. 21. Washer 22. Spring. 23. Valve-guide. 24 Admission-valve. 25. Valve-seat. 26. Igniter. 27. Porcelain. 28. Exhaust-valve. 29. Exhaust-valve seat. 30. Exhaust-valve stem guide. 31 Exhaust-valve stem. 32. Spring. 33. Collar. 34. Exhaust-valve operating rod. 35. Cam-roller controlling exhaust. 36. Thumb-screw. 37. Contact. 38. Platinum contact. 39. Screw-controlling platinum contact. 40. Distributing-crank bearing. 41. Distributing-gear wheel. 42. Distributing pinion. 43. Drain-cock. 44. Waste-pipe 45. Distributing-crank. 46. Cam-shaft for exhaust. 48. Piston. 49. Pin of piston-rod. 50. Oil-groove in frame.

the other side-shaft, which in turn is geared to the main shaft with two-to-one spur gears. The governor is driven from the first side-

shaft and simply regulates the position of the latch upon the gas-valve stem.

The Diesel oil-engine has come to the front for economy and as a motor in which any of the fuel-oils of commerce give most satisfactory results. It is of German origin and with the late improvements obtained from American suggestions in design and the modifications brought out from its extensive use in Germany, its details have been much simplified, and in the hands of the

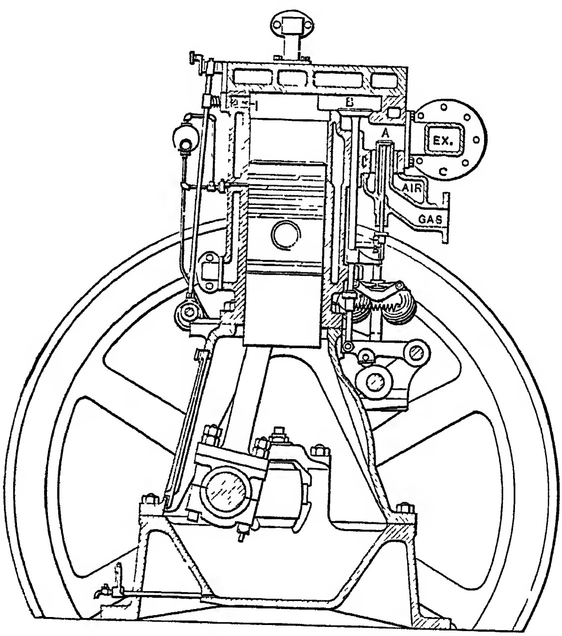


FIG. 174.—The Nash gas-engine.

Diesel Motor Company of America, whose office is at No. 11 Broadway, New York City, and factory at Worcester, Mass., it is now taking the lead for the larger powers and is especially adapted for operating electric plants. It is a two-cycle type and with duplex cylinders for driving electric generators brings the variation in light effect within one per cent. The points of difference from other explosive motors are a small clearance of about seven per cent. of the piston-sweep, high compression to about 500 pounds per square inch, sudden injection of liquid fuel at a still higher pressure,

and its spontaneous ignition by the heat of compression. Apparently there is no sudden explosion, but rather a gradual combustion of the charge of the sprayed oil and the oxygen of the hot compressed air during part of the stroke. The motor is of the four-cycle construction, operated on the two-cycle impulse, and is represented in its essential parts in the section (Fig. 175). The steel reservoir T is the high-pressure air-reserve, supplied by an air-pump P, driven by the motor through the rocker-arm Y, while the small pump Q, also operated from the same arm, supplies the fuel-

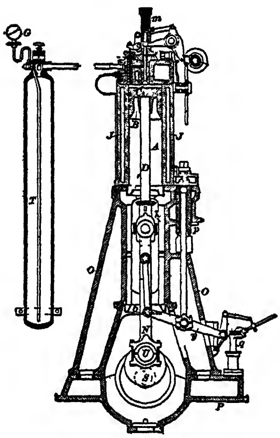


FIG. 175.—The Diesel engine.

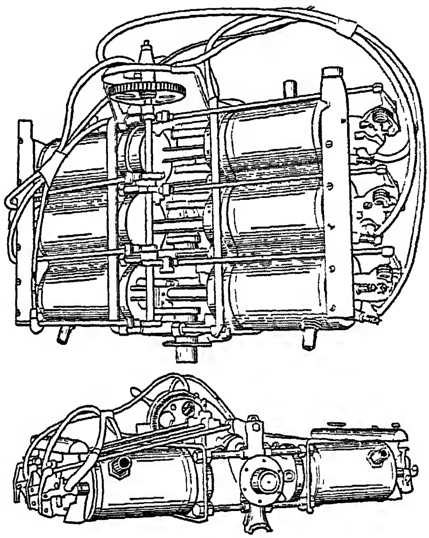


FIG. 176.—The light motor

oil at the required pressure to be injected with the high-pressure air used for spraying the charge. Further details are given in the general description of explosive motors. Also see indicator card, page 52.

One of the lightest gasoline-motors that we know of on record has been produced by the Duryea Motor Company, Reading, Pa. It is a six-cylinder motor of the opposed-cylinder type, working on a three-throw crank-shaft in a perfectly mechanical balance. Its four-cycle type gives the motor three impulses to each revolution, thus reducing the fly-wheel to the smallest dimensions and weight.

As it appears in the cuts it weighs slightly over 200 pounds, or less than five pounds per horse-power. With spark-coil, battery, fuel, and water-tanks partly filled, it weighs 232 pounds, or 5.7 pounds per horse-power. The cylinders are 4½-inch bore by 5½-inch stroke, with bearings of the same size as used in the company's regular automobile-motors. Jump-spark ignition is used, having a single coil and commutating the secondary current. The inlet and exhaust-valves may be removed from any cylinder-head by loosening a single nut. The crank-shaft and crank-pins are hollow for lubrication purposes.

This motor is believed to be the lightest for its power ever constructed and is another evidence of the mechanical development brought about by the requirements of the automobile.

One of the later designs for balancing the explosive shock is the balanced explosive motor of the Secor type in Fig. 177. The charge is fired in the chamber X, between the two pistons H H′ whose motion is transmitted to the cranks G G′, having equal throw and set at 180° apart on the crank-shaft.

The pistons are connected by

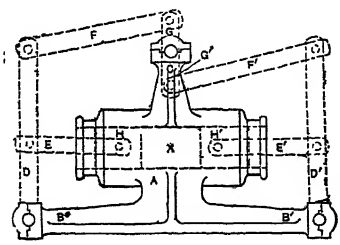


Fig. 177.—Balanced motor.

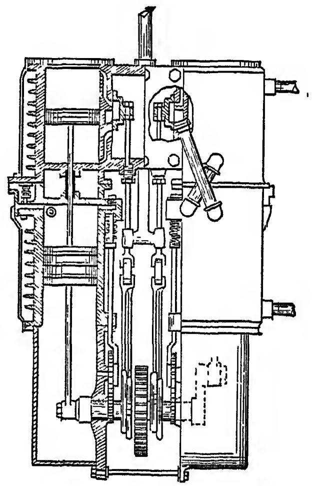


Fig. 178.—Combination motor.

the short connecting-rods H H′ to the vertical levers D D′, which transmit motion to the cranks through the connecting rods F F′.

A more curious than practical design of a motor is a combination of a steam and an explosive motor in one machine, as shown in Fig. 178, and is thus described:

In this design the piston of the explosive motor is made the

cross-head for the connecting rod. A duplex steam-engine with a duplex explosive motor as an auxiliary power in which the exhaust of the steam-engine may also be turned into the explosive-motor cylinder as an additional power and lubricant when the explosive motor is not in use.

In Fig. 179 is shown a section of the two-cycle marine motor of the Lozier Motor Company, Plattsburg, N. Y. The principal

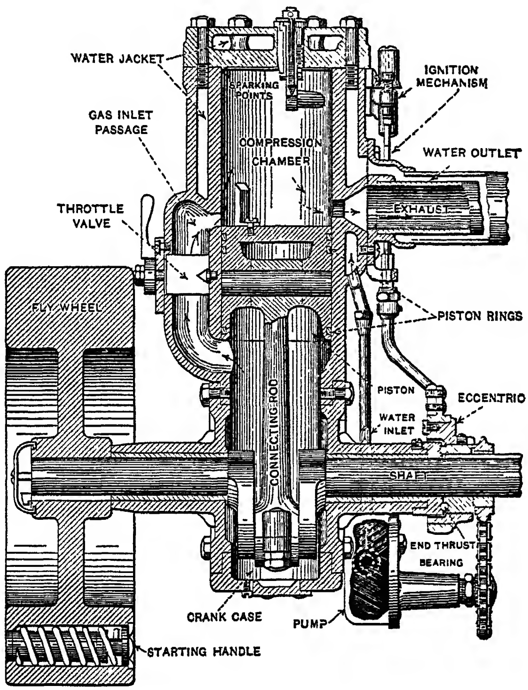


FIG. 179.—Lozier gasoline-motor.

features are the throttle-valve to regulate the charge from the crank chamber and the operation of the hammer spark-break from a cam on the shaft. A rotary circulating pump is driven by chain from the main shaft and the discharge of the water from the cylinder is around the exhaust-pipe. The thrust is taken by ball-bearings in the cam-hub. A throttle-valve in the passage from the crank chamber to the cylinder, with an index handle, regulates the charge. The starting handle is located within the rim of the fly-wheel and

held by a light spring. To start the motor the handle is pulled out and flies back the moment the motor starts by its own impulse, thus saving much annoyance from starting crank-wrenches.

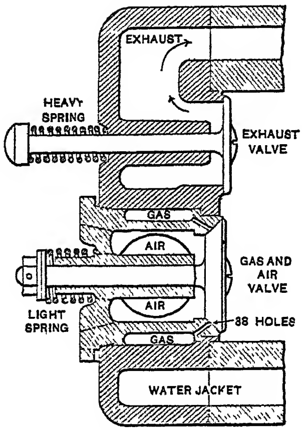


FIG 180.—The valves.

In Fig. 180 is shown a horizontal section of the cylinder-head of a motor designed by H. J. Perkins, Grand Rapids, Mich. It is seen that the fitting of the inlet-valve casing is recessed on its outside so as to make an annular gas chamber immediately behind the valve seat and through which 38 small holes are drilled around the face of the seat, thus making a simple and thorough mixture of the charge at the moment of entrance to the cylinder, the air entering through a side passage, as shown by the circle in the valve chamber. The motor is of the four-cycle type and the exhaust-valve governs by the hit-or-miss action from the fly-wheel centrifugal governor. The regulation is by holding open the exhaust-valve by a stop-lever that catches the push-rod when the valve is open and holding it until released by the governor. A single eccentric actuates

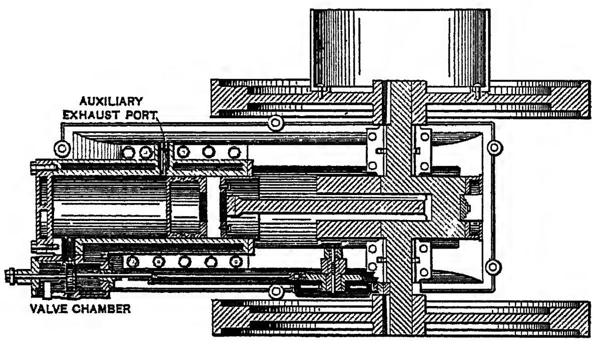


FIG. 181.—The Lazier motor. Sectional plan.

the four-cycle principle by a pick-blade that makes a miss-push at every other revolution.

It may be noticed that the valves in this design are as large as can be made practical in a cylinder-head and that the inlet-valve is larger than the exhaust-valve, which allows for a low lift for better mixing of the fuel and air.

The motors of the Lazier Gas-Engine Company, Buffalo, N. Y., have a peculiar valve-arrangement, which we illustrate in Figs. 181, 182, 183. The design is of the four-cycle type, with the hit-or-miss governing gear, but is peculiar in the fact that its exhaust-valve is the only one mechanically operated, and is so constructed that when the engine needs to miss an explosion it is held open,

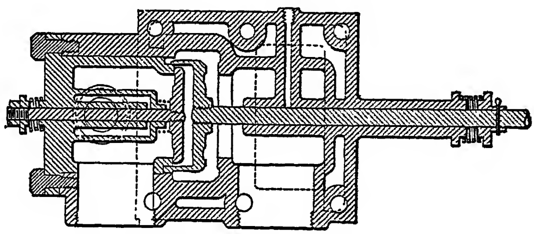


Fig. 182.—Vertical section of valves.

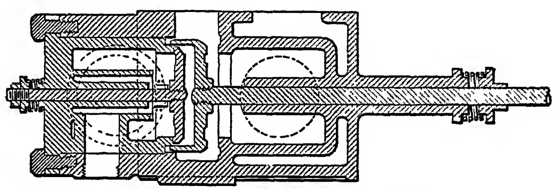


Fig. 183.—Horizontal section of valves

telescoping over the seat of the air-suction valve, cutting off all fuel supply, and allowing the piston to travel in the cylinder without compensation, during which time the valves remain in a state of rest. Fig. 181 shows a plan in section of the cylinder, while Figs. 182 and 183 are horizontal and vertical sections, showing the valve-mechanism upon a larger scale. Fig. 184 shows the position of the valves during a suction-stroke, the admission-valves *a* A being drawn open by suction, the explosive charge entering as shown by the arrows, and the exhaust-valve E being seated. On the next stroke the charge is compressed; the next is the explosion or working stroke. At the end of the power stroke the piston uncovers the

automatic port in the side of the cylinder, which allows the high-terminal pressure to be reduced, thus permitting the main exhaust-valve to open at atmospheric pressure, at which time the piston sweeps back, clearing the residue gas from the cylinder, and is then ready to take in a new mixture if governor permits, and on the next the exhaust-valve is held open, allowing the products of combustion to escape. All this time the pressure on the cylinder has been greater than the outside of the admission-valve, and there has been no tendency for the latter to open. In fact, during the exhaust-stroke the valve is in the position shown in Fig. 184, completely covering the admission-valve. When the speed exceeds the normal, the exhaust-valve remains in this position, so that on the suction-stroke there is no vacuum created, the exhaust-passage being open, and even if there were the admission-valve is effectively closed by the telescoping of the exhaust-valve.

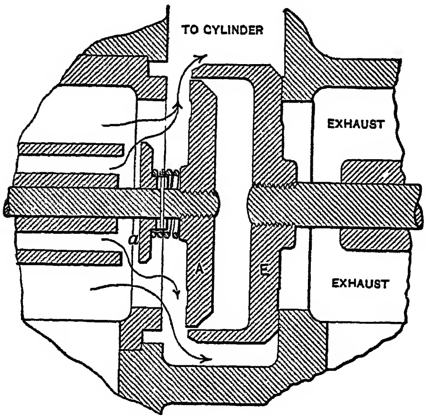


Fig. 184.—Inlet valve open.

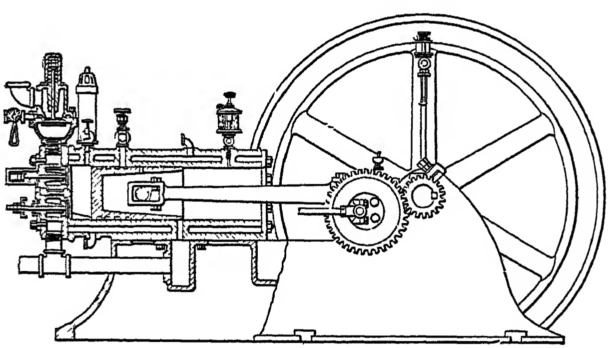


Fig. 185.—Section, Oil City Motor.

Neither is there any useless compression, the exhaust remaining open and the valve remaining motionless until another admission

is required. The air-suction and fuel-valves are mounted in a cage with ground seats with ports registering with openings in the valve chamber proper, thus allowing the valve cage to be taken out without disturbing the piping.

In Fig. 185 we illustrate in a vertical sectional view the "Oil City Motor," built by the Oil City Boiler Works, Oil City, Pa. An auxiliary exhaust by a cylinder-port is one of the features of this four-cycle motor. The gas-inlet and atomizing valve for gasoline, seen at the top of the cylinder-head, is an annular chamber around a perforated valve seat, with space between it and the final inlet-valve for thorough vaporization of the gasoline and mix-

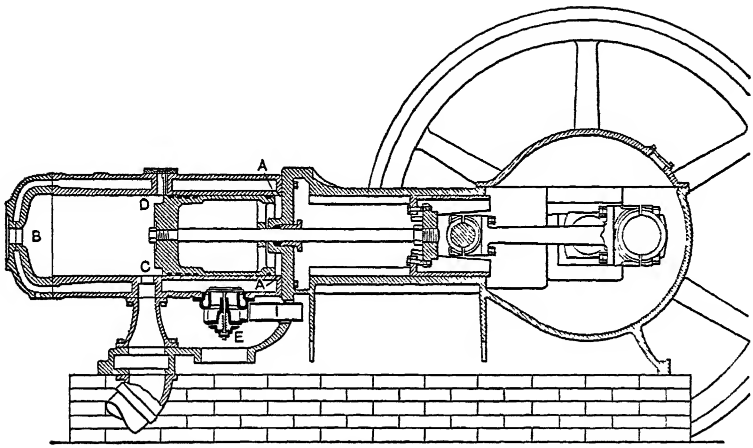


FIG. 186.—Longitudinal section of engine.

ing with the incoming air. In their smaller motors regulation is made by holding the exhaust-valve open by the governor. In the large motors the throttling system is used. Hot-tube or electric ignition as desired.

Valve-action of the Bessemer engine, of the Bessemer Gas-Engine Company, Grove City, Pa. The engine is of the two-cycle type and its operation is as follows:

During the backward stroke of the piston, Fig. 186, the mixture of air and gas is drawn into the front end of the cylinder through the port A, while at the same time the previous charge is being compressed in the back end or combustion chamber B. As soon as the

piston completes the stroke, the charge is ignited and the piston driven forward by the burning gases. When the piston reaches the end of the stroke in the direction of the shaft, the exhaust-port C is opened, and at about the same time the gas-port D, at the top of the cylinder, is opened, admitting the fresh charge, which was compressed by the piston during the working stroke.

The incoming charge enters the cylinder under moderate pressure and drives the burnt gases before it, thus filling the cylinder very quickly with the fresh mixture.

The air and gas are drawn into the front end of the cylinder through the gas-valve E, located beneath the cylinder, Fig. 187 being an enlarged view of this valve. The air enters through the large annular opening F, while the gas is admitted through a series of small holes or ports G. The valve H when seated closes the opening F and the small ports G, both being opened simultaneously by the valve, which is raised by the suction of the piston. Air enters the valve-body through the air-pipe I (Fig. 187), which is connected with the interior of the bed to avoid drawing in dust and dirt.

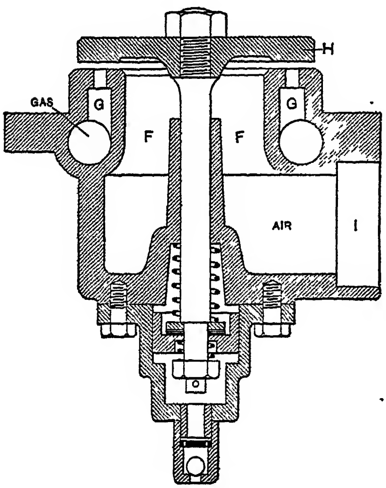


Fig. 187.—Section of air and gas valve.

The governor is located in the gas-pipe at the side and on a level with the top of the cylinder, the speed being regulated by throttling the gas and thus modifying the force of the explosion to meet the requirements of the load. The cylinder and back cylinder-head are water-jacketed, the front head having no jacket, since it is subjected to the low temperatures due to the slight compression of the fresh charge or mixture. This engine is provided with a piston-rod, cross-head, and guides the same as a steam-engine; in fact, the construction throughout is in accord with the practice in steam and gas engine-construction.

The stuffing-box in the front head is subjected to only moderate pressures and temperatures, consequently no trouble is experienced in maintaining a tight and durable joint. The working parts are enclosed by a neat hood and crank-case which not only prevent dust and dirt from reaching the vital parts, but render the engine self-oiling and adapted to making long continuous runs with the minimum of attention. The connecting rod is of the marine type and extra heavy. The pins are also large and provided with means for obtaining ample lubrication. The main shaft-bearings are provided with chain-oilers which ensure copious lubrication at all speeds, and at the same time prevent any waste of oil.

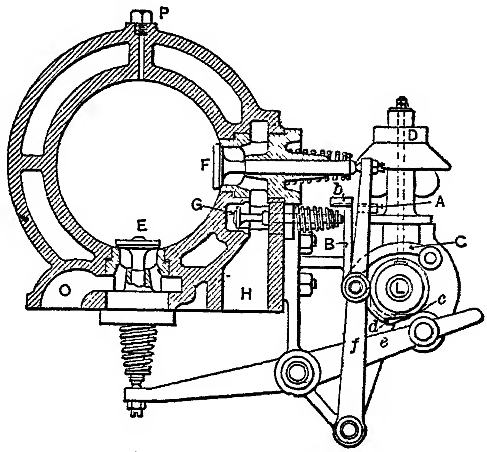


FIG. 188.—Valve gear.

The piston is oiled by means of a special automatic sight-feed oiler. The piston is very long, thus providing liberal wearing surfaces and is provided with four wide packing rings. The engine is not only very simple, but is unusually massive, being designed for all kinds of service for which gas-engines can be employed.

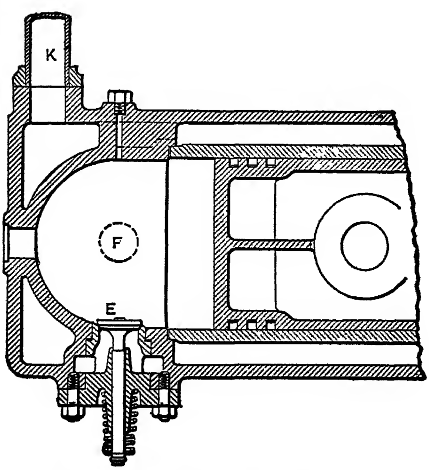


FIG. 189.—Cylinder and inlet valve.

The gas-engine of the Dudbridge Iron Works Company, Strand, England, has some peculiarities worthy of record, and which

we illustrate in Figs. 188, 189, and 190. The cylinder is overhung and bolted to the bed-piece and made in two pieces. The jacket and cylinder-head are cast in a single piece and the liner made of a specially hard mixture of iron for wearing quality and easy replacement when worn out. The valve-casings are all contained in the cylinder-head, which is spherical and water-jacketed. All valves are contained in casings with flanges and shoulder joints, easily removed for cleaning or repairs. Ignition is of the hot-tube type, as shown at J I, and the gas-inlet is regulated by an index-cock at V (Fig. 190).

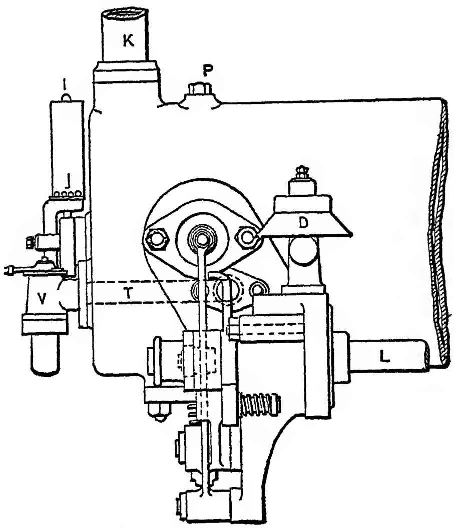


Fig. 190.—Governor and tube igniter.

The governor, as will be seen by reference to the illustrations, is of the fly-ball type, controlling the engine on the hit-or-miss principle.

The construction of the valve gear may be more readily understood by reference to the figures. All valves are worked from the reducing shaft L, which is driven from the crank-shaft by means of helical gears. F and G are air and gas-valves respectively, valve G opening directly into the air-inlet H. The exhaust-valve E opens directly into the exhaust outlet O. The air-valve F is driven through the lever *f* by means of the cam *c*. The exhaust-valve is controlled by the lever *e*, operated by the cam *d*. The gas-valve is opened by means of a small arm B, and the striker-blade A attached to the air-lever arm. Small arm B also carries a striker which is met by the striker-arm A as it moves toward the cylinder to open the air-valve. Arm B is under control of the governor through the arm C, and so connected that, as the governor rises, lever B is lifted and the striker *b* is lifted out of the path of A. In

this manner, when the speed rises above the limit, the gas-valve G is not opened, and the cylinder takes in a charge of pure air, thus miss-

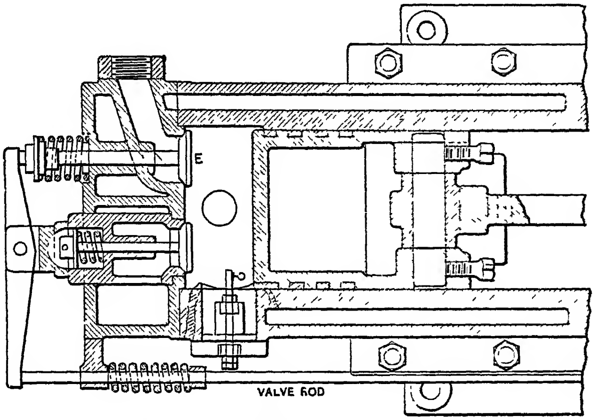


Fig. 191.—Section, Wayne motor

ing impulses and developing less power. The speed of the engine may be increased by putting on extra weights as shown at D, or the speed may be decreased by removing weights on the governor at D.

In Fig. 191 are shown some of the details of the "Wayne Motor," built by the Fort Wayne Foundry and Machine Company, Fort Wayne, Ind. A double cam on the reducing gear-shaft operates

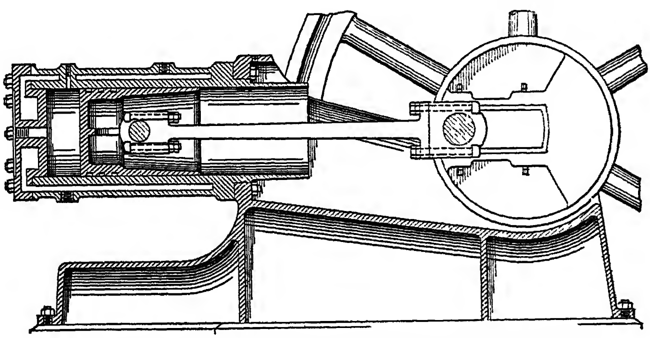


Fig. 192.—Longitudinal section of the Elyria gas-engine.

the exhaust-valve E through a push-rod and lever across the cylinder-head and also a supplementary gas-valve, independent from the free opening inlet-valve. The igniter of the make-and-break

type is operated by a pick-blade on the end of the firing-rod which engages with the arm of the igniter-spindle. The throw of the firing-rod is controlled by the governor.

In Fig. 192 is illustrated a section of the horizontal gas-engine of the Elyria Gas-Engine Company, Elyria, O. The section is on the central line and shows the method of bolting the cylinder to the base-frame, which is of box form. The cut shows all the parts of cylinder, piston, piston-rod, crank-balance weight, and fly-wheel radius in good proportions.

Fig. 193 shows a cross section of the cylinder, valve chamber, valves, and exhaust-valve bell-crank lever, a simple and compact device.

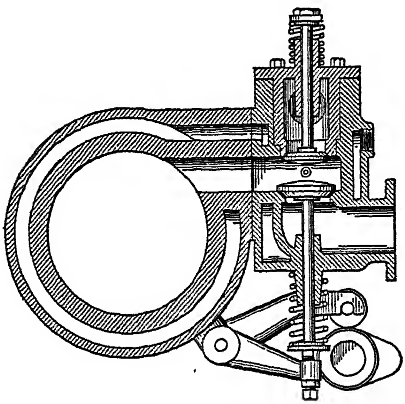


FIG. 193.—Cross section through the cylinder and valve chamber.

Ignition is by means of an electric spark, the plug for which is placed in the valve chamber between the inlet and exhaust-valve, where it has the benefit of the cooling effect of the incoming air, thereby prolonging the life of the sparking points. It will be seen that the inlet-valve is enclosed in a flanged bushing large enough to allow the exhaust-valve to be drawn out through the inlet-valve opening. A good construction design.

A NOVEL KEROSENE-OIL MOTOR

In Fig. 194 is illustrated the details of a kerosene vaporizing device as applied to a two-cycle motor, the invention of J. F. Denison, New Haven, Conn. Only pure air is contained in the crank-case and by this means the motor is made in a degree a scavenging one; the fresh air from the compression in the crank-case for a moment is blown into the cylinder before the opening of the vapor-inlet valve.

The method of operation is as follows:

Kerosene is kept in a tight tank or reservoir. Pressure is put on the fuel by connecting the upper part of the reservoir with the engine crank-case and interposing a check-valve V in the pipe between them.

The kerosene is drawn from the bottom of the reservoir and passes through a coil C in the combustion chamber, where it is turned into gas or vapor. While the engine is running the oil is heated to form the kerosene-vapor in the coil C and is then let into the cylinder through the poppet-valve P.

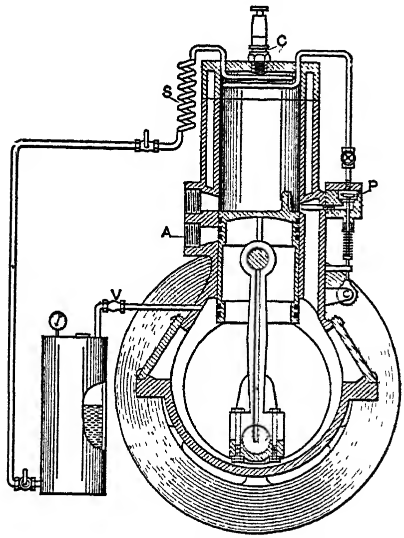


FIG. 194.—Section of motor.

This valve P is moved by a cam in such a way as to time the inlet of the gas a little later than the completing of the exhaust and a little later than the beginning of the inlet of fresh air from the crank-case. Incidentally the engine, like the old Day engine—the original two-cycle engine uses no inlet-valve to the crank-case, but uses an air-port which is uncovered by the piston at the highest point of its stroke.

In starting up, a secondary vaporizing coil S, in the supply-pipe outside the cylinder, is heated by a blow-torch. This coil S is kept heated only until such time as the heat from the explosions gets the coil C in condition.

The advantages of using kerosene in vapor form are very pronounced. In this condition it makes a perfect mixture, free from fine drops of liquid—such mixtures permit of much higher compression and much higher economy than is possible with oil spurted directly into the cylinder. A mixture of air and kerosene "gas" burns without depositing soot.

This engine is also designed with an air-starting device.

This starter supplies air through a poppet-valve moved by an eccentric, and since the air must pass through a check-valve before reaching the piston, it follows that the engine changes automatically from the air-starter to fuel-burning.

No vapor can reach the crank chamber from the vaporizing coil C, as the mechanically operated inlet-vapor valve P is closed during the up-stroke of the piston, and the check-valve V prevents vapor from passing to the crank chamber from the kerosene tank. The air-inlet port at A furnishes sufficient air at or during the terminal of the up-stroke of the piston.

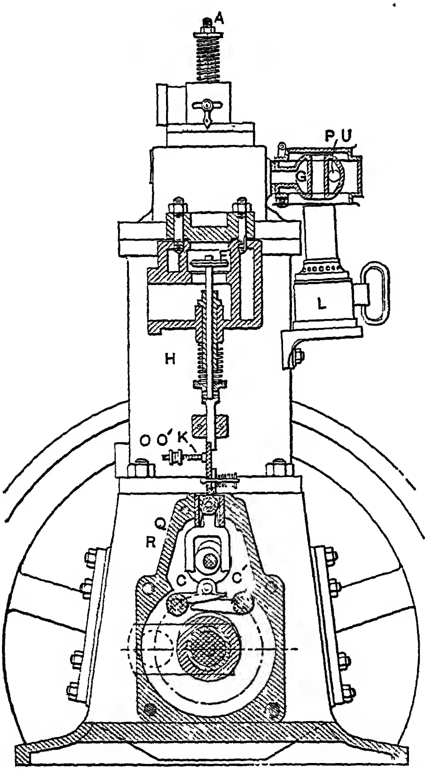


Fig. 195.—Millot engine, showing vaporizer and governor.

The air for starting is compressed in a small cylinder operated by hand or in multicylinder motors by the motor for storage.

THE MILLOT OIL-ENGINE

This is of French origin and has some novel features of construction. The oil, which is kept in a separate reservoir, comes into a chamber where it is kept at a constant level. The oil which is drawn into the engine passes through a spraying device to a very small opening which compels the oil to spurt out forcibly. This spraying is made still more active by the air coming from the valve C (Fig. 196), this valve being opened by the suction from the descent of the piston. The vaporized oil arrives by the opening P U (Fig. 195), in the gasifier G, which is a kind of cast-iron bowl kept at a dark-red heat by means of

an oil-lamp with Bunsen flame. The oil in vaporized state passes through the orifice G (Fig. 195) into the compression chamber and then into the cylinder.

At the end of the induction stroke, the cylinder and the compression chamber are filled with a mixture of gas and air. The piston, rising, gives a high compression to this mixture as it can occupy a volume only equal to that of the compression chamber. The pressure of the mixture striking upon the walls of the gasifier G (Fig. 196), which are at red heat, determines the time of explosion. After a few minutes of running, the heat produced by explosion is sufficient to keep the walls at red heat and the lamp L can then be removed.

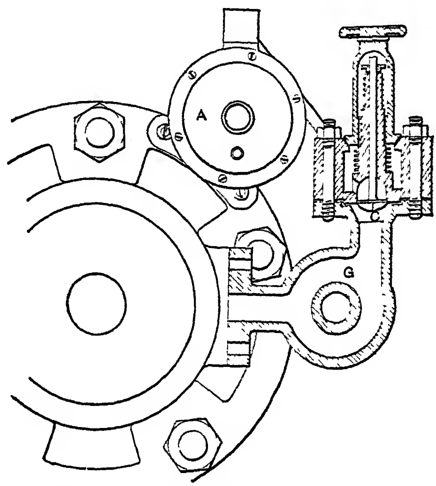


FIG. 196.—Petroleum-engine on the Millot system; top of cylinder.

The governor is a novel feature in a vertical engine, it being of the inertia type. This consists of a stem K, fastened to the side of the escapement, which is pivoted at the lower end. During normal running, the pawl is held by a spring in a vertical position. The catch C has an oscillating movement given it by the lever Q, which is driven by the cam R. The tension of the spring which holds the catch is such that the inertia of the weights O Ó is not sufficient to prevent the catch from following this movement when the engine turns at its normal speed; but when this passes the proper limit, the inertia of these weights makes the catch oscillate and leave its contact with the stem of the escapement. Consequently the valve F is not raised by the escapement and there is no exhaust, the cylinder retaining the products of combustion from the preceding explosion. No explosive mixture is drawn in, therefore, and no ignition can be produced so that the motor slows down. When the engine reaches its

normal speed, the governor ceases to act and exhaust commences again.

Fig. 197 is a cross section of the Wayne gas and gasoline-engine, showing the position and operating gear of the gas-valve, inlet-valve, and exhaust-valve.

The operating cam, which is mounted on a short secondary shaft geared to the main shaft, throws the rocker-arm to the left, this movement being imparted to the valve-rod opens the exhaust-valve A. The spring D returns the rod when it is released by the cam and opens the gas-valve C, as the spring D is much stronger than the seating spring on the gas-valve stem. The gas-valve delivers fuel to the valve B, which is opened directly into the combustion chamber by atmospheric pressure. Thus during a normal charging-stroke the valve-rod is entirely released by the cam, and by means of the spring D holds open the gas-valve, which it releases at the end of this stroke, and the rod takes an intermediate position during the compression and working strokes. At the end of the working stroke the cam comes into position and pushes the valve-rod clear out, thus opening the exhaust.

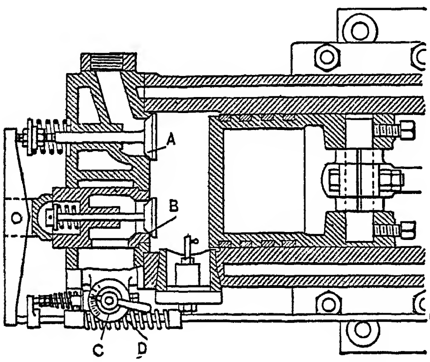


FIG. 197.—Cross section of cylinder and valves of the Wayne engine.

This cycle is repeated so long as the speed is at or near the normal value, but when the speed is excessive the governor raises the end of a latch, which engages a lug on the rocker-arm actuating the valve-rod, thus holding it back and allowing the gas-valve to remain closed so that air only enters the cylinder through the admission-valve.

In Figs. 198 and 199 are shown the details of the valve gear, valves, and ignition gear of the Blaisdell double-acting four-cycle engine, having two cylinders placed tandem.

The valves, which are shown in Fig. 198, are of the poppet type,

working vertically, and are held to the seats by means of springs. The inlet-valve, it will be noticed, is located immediately above the exhaust-valve, thus causing the incoming charge to impinge upon it and to pass over the exhaust-valve, thus keeping the temperature comparatively low and rendering it unnecessary to circulate water through the valves. The inlet-valve is placed in a cage, which is readily removable, thus exposing the exhaust-valve, the latter being readily removed through the opening normally filled by the cage.

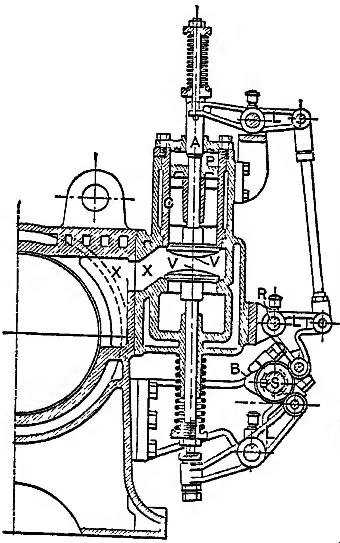


Fig. 198.—Section of valves.

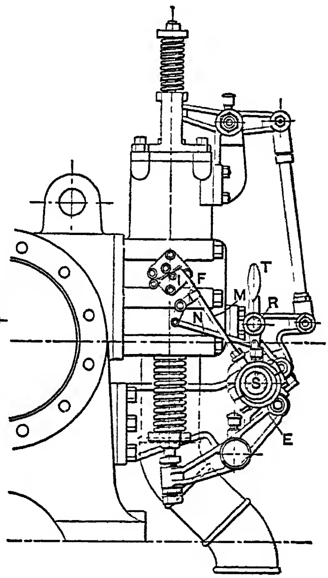


Fig. 199.—Valve gear.

The exhaust-valve chamber is water-jacketed, thus preventing the overheating of its stem and guide.

The igniter and valves are operated by means of a cam on the side-shaft, one cam being used to operate both the inlet and exhaust-valves. The igniter mechanism is illustrated in Fig. 199 and represents a special form of make-and-break contact operated by the eccentric. The eccentric-rod rests in a small forked timing lever forming one arm of the rock-shaft, which, however, is not a part of the igniter proper, thus permitting the latter to be removed without disconnecting or otherwise disturbing any other parts.

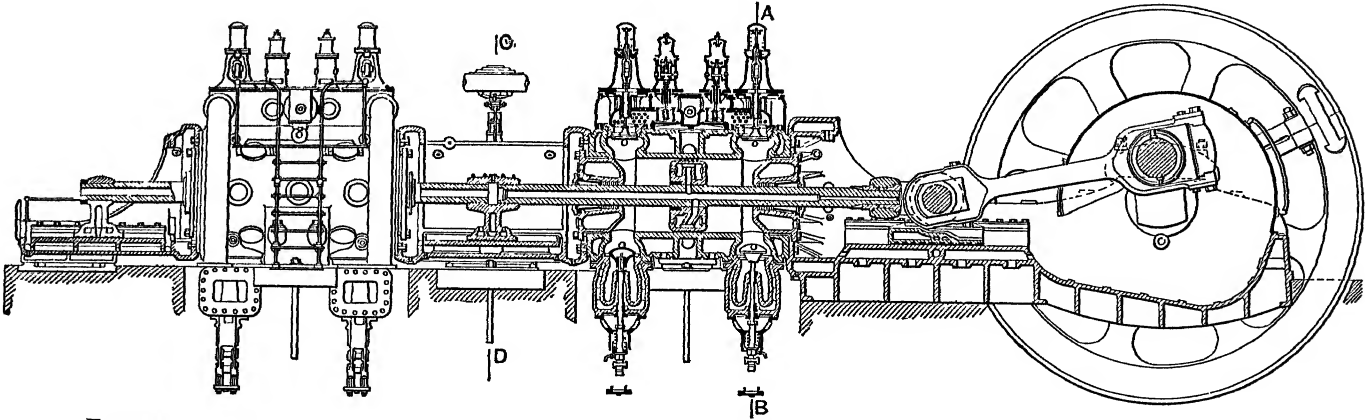


Fig. 200.—Section and view of the two-cylinder, double-acting, four-cycle engine for blast-furnace fuel. Nurnberg type.

The engine is started with compressed air, one cylinder being operated by air pressure until the other cylinder receives an impulse, after which the engine continues to run on its own fuel.

THE NURNBERG GAS-ENGINE

The following illustrations present the more important, as well as the especially interesting, features of the Nurnberg gas-engine as built by the Allis-Chalmers Company, Milwaukee, Wis. This engine has been designed especially for the use of blast-furnace gas and consequently all the details of construction have been developed with a view to adapting the engine to the perfect utilization of this fuel, as well as coke-oven gas, producer gas, and Mond gas.

Thus far the Nurnberg engine has been built in large sizes only, viz., in units ranging from 250 to 3,200 actual horse-power.

The engine is of the four-cycle, double-acting type. The operations taking place at each end of each cylinder are on the Otto cycle, hence the results accomplished in each end of the cylinder are the same as in the single-acting Otto engine, and, therefore, each end of the cylinder is provided with three distinct valves. First, the inlet-valve, admitting either air or combustible mixture into the cylinder; second, the gas-valve, regulating the amount and period of gas admission to the cylinder for each impulse, and third, the exhaust-valve.

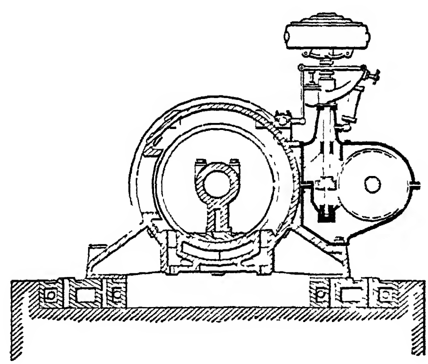


FIG. 201.—Section of piston-rod guide

Fig. 200 is a longitudinal section of the engine, showing the general arrangement of the interior and the location of the valves, while Figs. 201 and 202 are cross sections between the cylinders and through the valve chambers, respectively. The inlet and exhaust-valves are of the usual poppet type, positively operated by a simple form of valve gear, a general view of which is shown in Fig. 203.

The inlet-valves open approximately when the crank reaches one dead centre and close approximately when the crank reaches the opposite dead centre. The gas-valve is operated by a governor-controlled mechanism illustrated in Fig. 202. This type of gear is what is known as the "Marx" patent gear, which has proved to be especially well adapted to operating the valves of large-sized gas-engines.

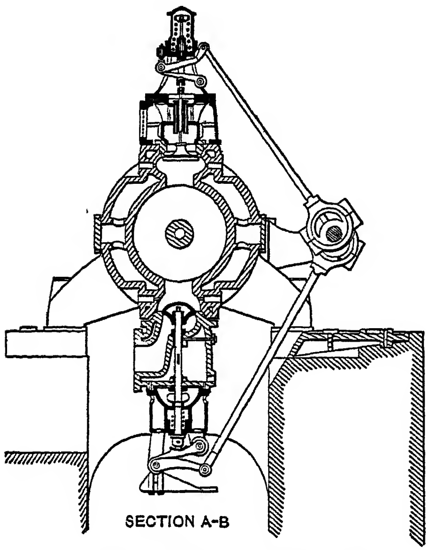


FIG. 202.—Section through valves.

Referring to Fig. 203, the forked rod A is actuated by an eccentric on the lay-shaft, the upper end of A being carried by the swinging link B. To the pin C is pivoted the hook D, which engages the outer end of the rolling lever E, the inner end of which is connected to the gas-valve stem. Lever F is provided with a curved upper edge, upon which lever E rests. One end of the lever F is fulcrumed upon a pin fixed in the valve-bonnet, while the outer end is raised and lowered by the arm G, which is actuated by the governor through the arm I.

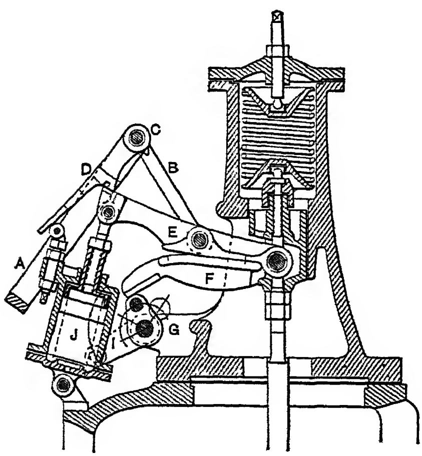


FIG. 203.—Gas-valve mechanism.

When the outer end of lever E is drawn downward by the hook D, the rocking motion imparted to E lifts the inner end, and with it

the gas-valve, the hook releasing the lever E at the end of the piston stroke. The easy seating of the gas-valve is assured by means of the dash-pot J. It will be seen that as the outer end of the lever F is lowered by the governor, the motion of lever E is modified so that the gas-valve is lifted later in the stroke of the piston. Thus, by varying the position of the lever F the opening of the gas-valve can be effected at any point in the stroke according to the power demand and the consequent speed and position of the governor. The gas-valve opens quickly and closes instantaneously, but is prevented from pounding the seat by the dash-pot. The exhaust-valve is opened by a simple rolling lever operated by an eccentric on the lay-shaft as shown.

The results obtained by this simple valve gear are the opening and closing of the air and mixing valves, as well as the exhaust-valves, while the crank is close to the dead centres, and the opening of the gas-valve earlier or later in the stroke according to the variations in the load. The retardation of the opening of the gas-valve is accompanied by a proportionate throttling of the gas.

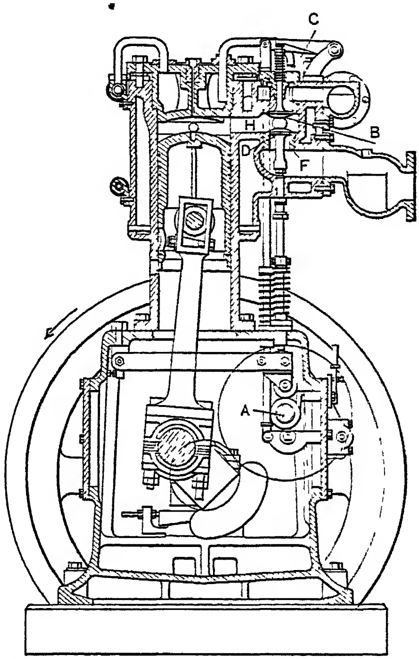


Fig. 204.—Section of Westinghouse vertical engine

The Westinghouse vertical motor is a model of compactness and is shown in sectional detail in Fig. 204, and as built for natural gas has a usual compression of 120 pounds, with an explosive pressure of 350 pounds per square inch, exhausting at 30 pounds at full load, which decreases as the load falls.

All valve movements are operated from a single-cam shaft A. One of the features in this design is the location of the admission

and exhaust-valves in line, and both operated by push-rods and levers from cams on the shaft A, both valves being held to their seats by springs. The admission-valve B is mounted in a bonnet C, and can be removed without removing other parts. This also allows room for taking out the exhaust-valve and its seat F when required.

Duplex hammer-spark ignition is employed and, when convenient, with a direct reduced current from a lighting circuit. A conspicuous feature in this design is the housing of the cranks, trunk-pistons, cam-shaft, cams, and push-rod rollers; all of which can be quickly got at through movable doors in the box-frame.

In the sectional view (Fig. 205) are shown some of the details of construction of the double and opposite-cylinder engine of the American type of the Crossley engine.

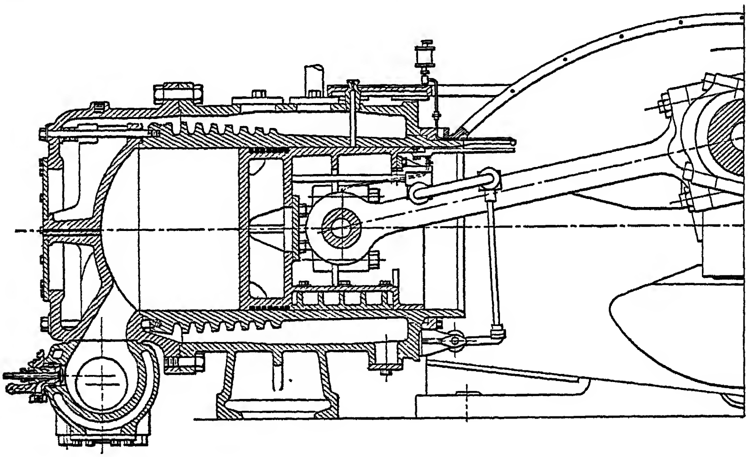


Fig. 205.—Sectional view of one-half of engine.

Some notable features of this design are the casting of the cylinder, water-jacket, cylinder-head, and exhaust-valve chamber in separate pieces and bolting them together. This allows of the novelty of water-cooling ribs on the cylinder. The water cooling of the piston for large engines is accomplished by circulating sections in the piston and a flexible pipe-connection to traverse with the piston.

The crank-shaft has a centre-crank and the connecting-rods work on one crank-pin, one rod having a single box and the other a forked end with a box in each fork.

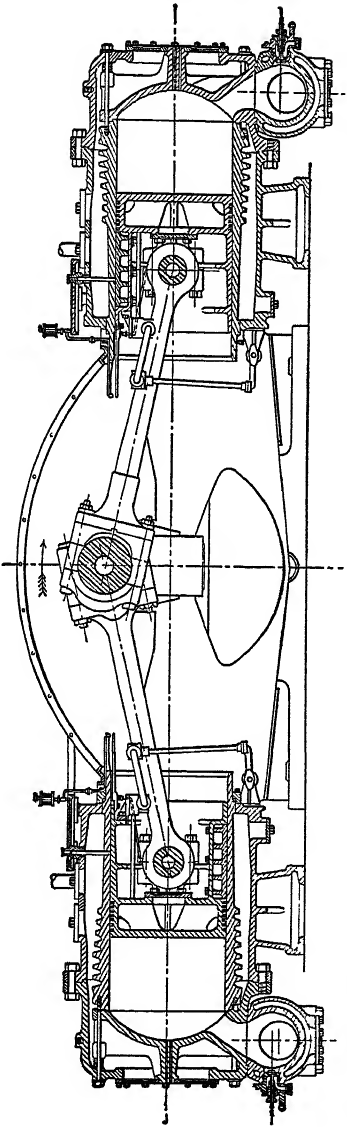


FIG. 206.—Section of the opposed two-cylinder American Crossley gas-engine, as built by the Power and Mining Machinery Co., New York City. In sizes from 150 to 650 horse-power.

In Fig. 206 are shown the details of a double engine working upon a single crank and pin, one rod having a single box and the other a forked end with two boxes.

In Fig. 207 is shown a section of a water-cooled balanced exhaust-valve used on the American Crossley engine.

It is of the poppet type and the relation between the valve and its seat is the same as in the ordinary mushroom form of valve. An oscillating arm, receiving motion from the cam on the secondary shaft, operates the valve. The valve and stem are hollow and water for the purpose of internal cooling is conveyed through the pipe shown at the top in the cut. The water escapes around this pipe through a second pipe, the direction being indicated by arrows. This valve has the unusual advantage of travelling in double guides, one on each side of the exhaust, which prevents the pressure from within from throwing it out of alignment with the seat. Oil-ducts, for the purpose of lubricating the guides of the valve-stem and valve-shell, are shown in the cut. The exhaust-valve chamber is a separate piece, bolted to the under side of the cylinder, and can be taken off without interfering with any other working parts of the engine.

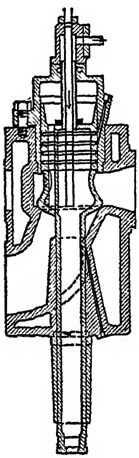


FIG. 207.—Water-cooled balanced exhaust-valve.

In Fig. 208 are shown the vaporizer and water-cooled valve chambers of the new Crossley oil-engine. It is essentially a kerosene and distillate-oil engine, but a claim is made that crude oil may be equally useful as explosive fuel. It will be noticed in this design that an air-snifting valve makes a water-spray into the vaporizer near to the oil-spray inlet, making an explosive compound of oil, air, and water-atoms to be ignited by compression and an igniter-tube projecting within the vaporizer, as shown in the small cross section.

The outside ribs on the vaporizer facilitate the heating of the chamber when starting and are also for regulating the temperature while the motor is running.

The water element in this combination of explosive fuel allows of excessive compression without preignition, otherwise possible.

In Fig. 209 is represented a detailed section of a late type of the Olds gasoline-engine. A notable feature, apart from the position

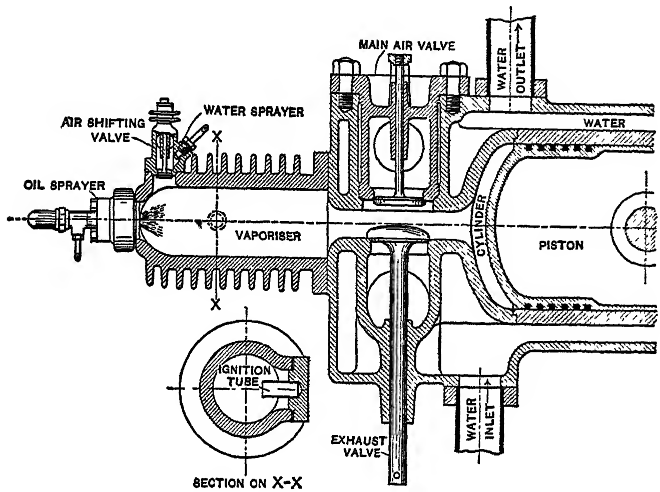


FIG. 208.—Section of vaporizer and valve chamber. New Crossley.

of the valve chambers in the head of the cylinder, is the making of the cylinder and jacket in two pieces bolted together by contact with the head, which is bolted to lugs on the cylinder.

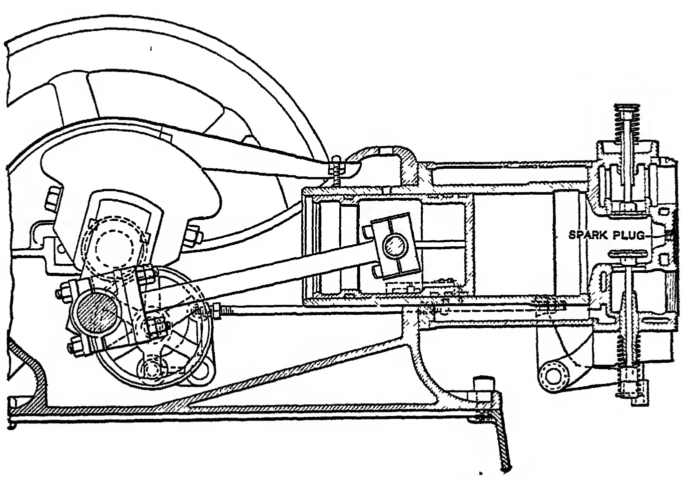


FIG. 209.—Section of type A, Olds engine.

The inlet-valve and seat are encased in a double-seated flanged cage, which is easily removed to allow the exhaust-valve to be drawn out through the opening.

The exhaust-valve is operated by a cam on the reducing shaft, two bell-cranks, and a push-rod.

In Fig. 210 is shown a vertical section of the Walrath three-cylinder engine of the four-cycle type, and in Figs. 211 and 212 a plan of the cylinder-head and valve-levers and a vertical section of the water-cooled exhaust-valve as applied to the larger engines of 50 horse-power.

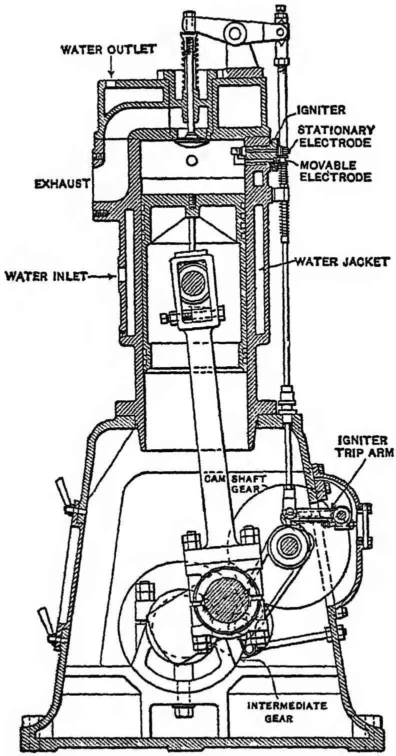


FIG. 210.—Cross section of vertical engine.

The general style of construction is shown in Fig. 210, which gives a cross-sectional view of the engines with cylinders 12 × 12 inches or smaller. The base, cast in one piece, is bored to receive the cylinders, crank, and cam-shaft bearings. The main bearings, being a separate casting made to fit a corresponding circular bore in the base, can readily be removed without disturbing the crank-shaft.

The cylinders are bolted on the top of the base, fitting into the bore made to receive them, as shown.

The valves, of the poppet type, are two in number, one serving as the inlet for the explosive mixture and the other acting as the exhaust-valve. In all engines of over 10 horse-power the valves are placed in cages which fit into the cylinder-head. By having the joint between the cages and the head ground, it is the work of but a few minutes to remove either valve when desired. In the larger engines a special water-cooled valve, illustrated in Fig. 212, is employed.

The valves are operated by a cam-shaft revolving at just one-half the speed of the crank-shaft. This is accomplished by a train of three spur gears, which, with those used to drive the governor, are the only gears used on the engine. This cam-shaft operates both the valves and the igniter for all of the cylinders.

The pistons are extremely long to give enough surface to reduce the wear on the cylinder and pistons to a minimum. This is a vital point in cases where the piston must perform the additional services of a cross-head, for when short, undue wear will result, giving necessity for extensive repairs and large repair bills.

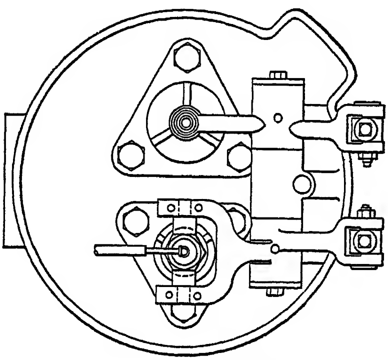


FIG. 211.—Cylinder-head and valve-levers.

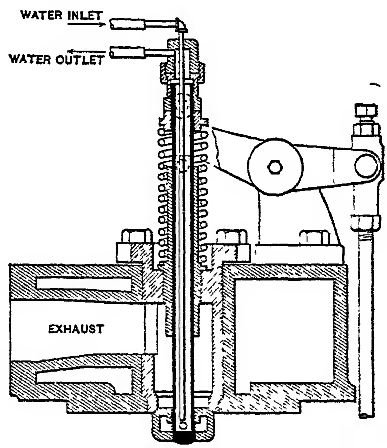


FIG. 212.—Water-cooled exhaust-valve.

To reduce the friction and wear on the pistons from the angularity of short connecting rods they are all made three strokes in length. The boxes at both ends are of bronze, while the rod itself is of forged steel.

The igniter is of the break-type and consists of a casing holding two electrodes, one of which is stationary and insulated from the main body of the casting. The other electrode is movable and operated by a cam, which causes it to make and break contact with the insulated electrode. The contact points are composed of a special metal, which is adapted to withstand great heat.

The governor is of the fly-ball type, driven by means of bevel

gears. It operates a piston-valve which regulates the amount of explosive mixture required for each impulse to maintain a steady speed under all conditions and variations of load. This method of governing gives an impulse every second revolution for the one-cylinder type, every revolution in the two-cylinder, and every two-thirds of a revolution in the three-cylinder type, no matter what the load may be.

A starting device is provided upon all engines above 20 horse-power, and can be supplied on the smaller sizes. An air-pump, gen-

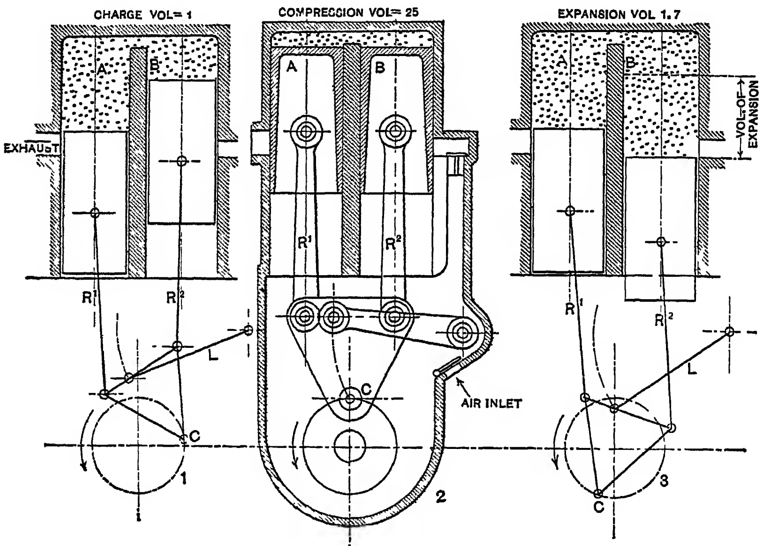


FIG. 213.—The Lister two-cylinder motor.

erally driven by a small pulley on the engine crank-shaft, charges a storage tank with air at a pressure of from 100 to 200 pounds. A starter-lever of the piston type, operated by a cam, admits the air above the piston, which moves downward. The valve then opens communication between the engine-cylinder and the atmosphere, which causes the air to be exhausted. The engine goes through a series of such operations until an explosion of the gases takes place.

In Fig. 213 we illustrate a two-cycle design of English origin (the Lister), in which two pistons are connected to a single crank-pin, by which a direct impulse is given to the crank when it is on the

centre. The three positions of the pistons and crank-pin are shown in the three sections of the cut.

It will be seen that two cylinders, A and B, are arranged parallel to each other above the crank-shaft, A being the exhaust and B the inlet-cylinder, connected by a common compression chamber at their inner ends. The pistons are joined by the connecting rods, R^1 and R^2, to two corners of the triangular frame, as shown, the other corner being attached to the crank-pin C. The movement of the frame is constrained by the radius-rod L, the other end of which is jointed to the casing of the engine. Ignition of the compressed charge takes place when the pistons are in the position shown by 2. The crank rotates in the direction of the arrow, so that piston B travels faster than piston A, and has approached the end of its out-stroke by the time the latter piston has arrived at the exhaust-port. Their positions are then as in 3. When the exhaust-port is uncovered the pressure drops to atmospheric, and piston B, then passing an inlet-port communicating with the enclosed crank chamber, allows a volume of air to pass through the check-valve into the cylinder B, in order to scavenge the cylinders from the products of the previous explosion. The piston B then commences its stroke again in advance of piston A, forcing out a quantity of air, and nearing the end of its in-stroke at the time the exhaust-port is closed by piston A. The position of the pistons before compression is shown in 1. Shortly before the closing of the exhaust-port a charge of gas or gasoline is pumped into the cylinder B, forming an explosive mixture with the air previously drawn in. In engines, the close governing of which is not essential, the charge may be drawn into the crank chamber with the air, and thence delivered to the cylinder, thus doing away with the necessity for pump-charging, though the advantages of scavenging are lost by this arrangement. The mixture is compressed as the pistons approach the upper end of the cylinders, ignition is effected by any of the usual methods, and the cycle is repeated as before, one explosion taking place to every revolution of the crank-shaft. It will be noticed that the initial volume of the charge is increased by from 50 to 70 per cent. before the exhaust, allowing more work to be obtained from the fuel together with a lower exhaust pressure. The ratio of expansion volume to compression volume is as 6 to 8. The design permits of

the connecting rods being kept very short, and they are so proportioned that at no point of the stroke do they make a greater angle with the centre line of the cylinders than 5°; thus the pressure on the cylinder walls and the consequent wear are very small. The com-

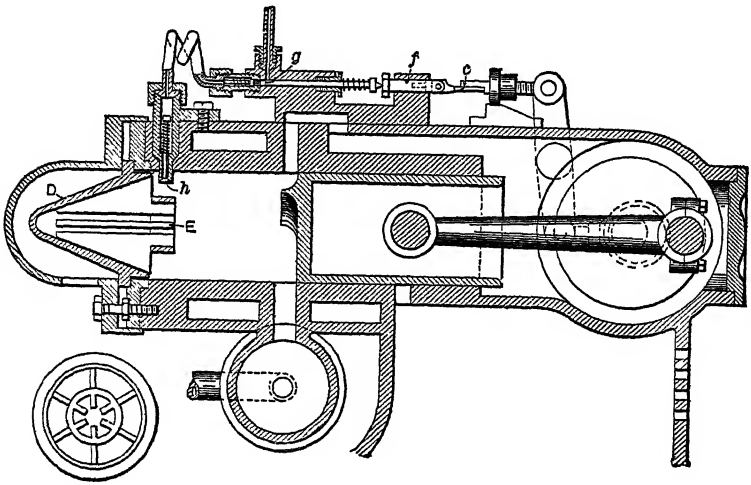


FIG. 214.—Section Weiss kerosene-oil motor.

bined effective-power strokes of the two pistons are approximately equal to 1.8 times the crank-stroke, the compression portion of the return-stroke amounting to 1.2 times the crank-stroke.

In Fig. 214 is illustrated the working detail of the Weiss kerosene-oil engine in a sectional elevation showing the conical vaporizer E D enclosed in a shell for confining the lamp flame when starting and to keep the outer walls hot when the engine is running.

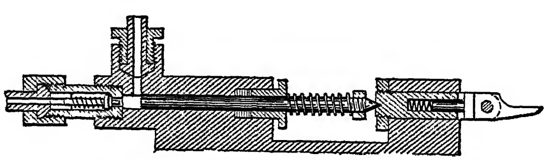


FIG. 215.—Oil-pump and pick blade

A front view of the vaporizer at the lower left-hand corner of the cut shows the extended web surface. The small spring-held oil-valve at *h* holds the oil between it and the pump intact during the impulse-stroke. The small oil-pump at *g* is operated

by the pick-blade *c*, with a hit-or-miss charge, governed by the momentum of a small weight sliding on an inclined plane, the amount of charge and the interruption being readily adjustable.

In Fig. 215 is shown an enlarged section of the oil-pump and pick-blade. The injection by the movement of the motor-piston is of pure air drawn into the crank-case by the forward motion of the piston and compressed; when at the opening of the cylinder-port at the end of the impulse-stroke, the compressed air is injected into and guided to the head of the cylinder to meet the vaporized oil in the vaporizing cone. Compression and the heat of the vaporizer fire the charge at the proper moment.

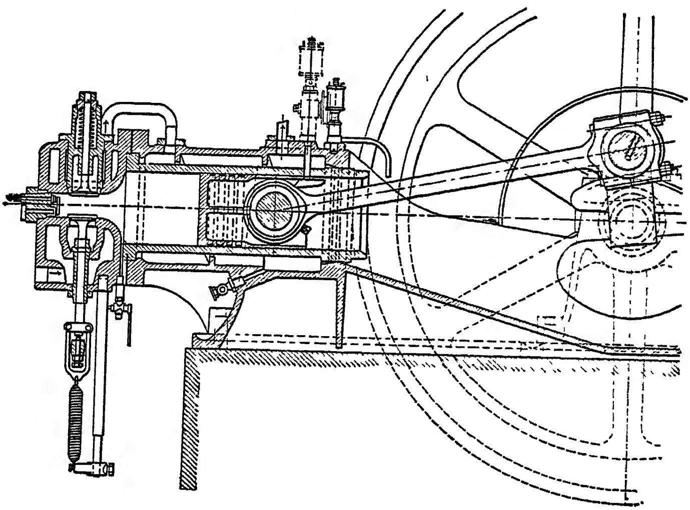


FIG. 216.—Sectional elevation of Bollinckx gas-engine.

In Figs. 216, 217, 218 we illustrate some of the details of a novel type in a four-cycle gas-engine of the scavenging type, made by the Société Anonyme des Moteurs à Gaz A. Bollinckx, at Buysinghen, Belgium, in which compression is carried up to 165 pounds per square inch, and a special scavenging arrangement expels the burnt gases after the explosion, thereby increasing the efficiency and preventing premature explosion. The governor is of the hit-or-miss type, and ignition is effected by electric spark, produced by a magneto machine.

The frame is very heavy and strong, being cast in one piece in the smaller sizes, and is designed to serve as an oil catcher. The bearing brasses are in four parts, of cast iron lined with white metal. The cylinder, which is shown in section in Fig. 216, is separate from the frame, and the latter is provided with spiral fins in the water-jacket, so that the cooling water is compelled to follow a spiral path round the cylinder, producing the maximum effect. On withdrawing the cylinder it is easy to clean the water spaces of sediment and incrustation. The crank-shaft is of steel and is provided with rings to receive oil from a fixed lubricator, the oil being driven into the crank-pin by centrifugal force. Complete automatic lubrication has been avoided, as the makers believe that the attendants trust too implicitly in such devices, with the consequence that accidents result The crank-shaft is very massive, and is fully counterbalanced by counterweights attached to the crank-webs. The crank end of the connecting rod is fitted with phosphor-bronze bushings, and the small end with a cylindrical cast-iron bushing, working on a pin of hardened steel.

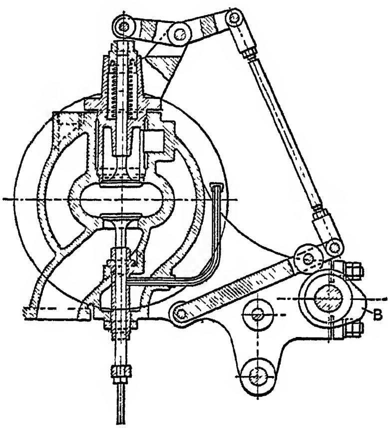


FIG. 217.—Section through admission and exhaust-valves.

The piston, as usual, is provided with a large surface bearing on the part of the cylinder which is not directly heated by the hot gases, the diameter of the piston being reduced at the back end. Only one ring is exposed to the highest temperature, the remainder working in the cooler portion of the cylinder. The admission and exhaust-valves work vertically, as shown in Fig. 217, the former above the latter, and are especially easy to inspect, while their arrangement tends to prevent wear. A drain-cock, shown in Fig. 216, permits the removal of oil, which might collect in the bottom of the cylinder and cause premature explosions. The valves are driven by means of a cam-shaft and cam B (Fig. 217), actuated from the

main shaft by skew gear; at the end of the explosion-stroke the exhaust-valve is opened and allows the burnt gases to escape, and at the end of the return-stroke the admission-valve is opened to admit the scavenging current of air, which is sucked in by virtue of the high velocity and inertia of the exhaust gases, producing a partial vacuum in the cylinder. The vertical arrangement of the valves is more costly than other systems, but has been preferred on account of its superiority.

The cylinder is lubricated by a special sight-feed lubricator, with a catch-feeder for the piston-pin.

Ignition is produced by means of a small magneto-dynamo carried on the engine. Inside the cylinder there is a fixed insulated contact and a finger, which normally rests against the contact, under the control of a spring. The armature of the magneto C (Fig. 218) is pushed round through an angle of about 90° by lever A, operated by the cam-shaft, and on its release is quickly pulled back by spring R, thus causing a momentary but powerful current to flow through the finger to the contact in the cylinder; at the same moment the finger is suddenly drawn from the contact, breaking the circuit and producing a very intense spark.

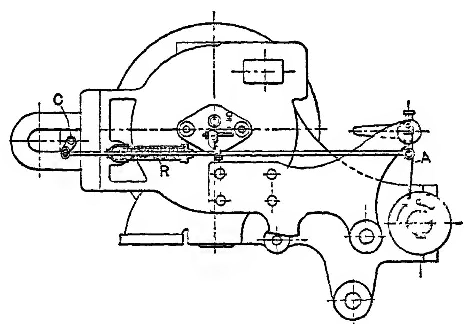


FIG. 218.—Ignition mechanism.

Moreover, the spark is just as intense when the engine is being started, and the compression is weak, as when the engine is running at full speed. The action of the igniting device is a most novel one and well worthy of study in regard to the part revolution of the armature of the magneto generator, taking place at a uniform speed at the starting of the engine, however slow, and the trip of the circuit-breaker at a positive and adjustable time.

The governor is of the centrifugal type, with provision for adjusting the speed while running, and actuates a small fork which determines whether the admission-valve shall be opened or remain closed for one or more cycles.

THE SCAVENGING ENGINE

A slight increase in the power of an explosive motor is claimed from the discharge of the products of combustion in the clearance space at the moment of the close of the exhaust-stroke, by holding open the exhaust-valve until the crank is slightly passed the centre and mechanically giving a free opening to the air-inlet valve or a supplementary valve arranged to give a free air-inlet at the right moment.

The addition of a lengthy exhaust-pipe, with bends instead of elbows, gives the rapid-flowing exhaust a momentum that produces a slight vacuum or draught in the combustion chamber and through the air-inlet valve, which sweeps out the products of combustion and fills the clearance space with fresh air, while the piston is nearly stationary at the end of the exhaust-stroke. An exhaust-pipe of about 100 times the length of the stroke, with the muffle-pot at the end of the pipe, has been found to give the best effect. A saving of about 20 per cent. per brake horse-power has been shown by scavenging over non-scavenging engines as constructed by the Crossleys in England. For this type the valves must be located on opposite sides of the cylinder and so arranged that the gases of combustion will pass out with as little friction as possible. The Crossley four-cycle scavenging engine was designed with curved cylinder-head and piston-head to conform to least friction, but any motor with valves in line on opposite sides of the cylinder can be given the scavenging effect, more or less efficient according to the valve and exhaust-pipe arrangement.

Nor is it necessary to adjust the inlet-valve for air alone to enter at the moment of scavenging, as there can be but little loss in scavenging with the explosive charge. A considerable increase in the explosive pressure may be obtained, with a consequent increase in the power of the motor, from a full charge of explosive elements.

COOLING RADIATORS FOR WATER-JACKETED AUTOMOBILE MOTORS

Experiments in cooling the water of the cylinder-jackets of automobiles has shown that a dead-black surface is the best liberator of heat from the circulating water and that black-iron pipe is supe-

rior to copper or brass. If the iron pipe is tightly wound with No. 10 black-iron wire one fourth of an inch apart, the efficiency of the cooling-coil will be largely increased.

Rapid circulation of the water is also a factor of the best work of the radiator. The proportion of heat-unit power in an automobile varies greatly with the speed, as does also the air-cooling effect; so that at all speeds a given-size radiator should control an even water temperature.

The proportion of total radiating surface in the cooling coils when placed in front with a free access of air varies somewhat with makers, but many approximate 30 square inches for each square inch of heating surface that is water-jacketed in the cylinders.

The driving of a fan behind the radiator for drawing air through it when hill-climbing, or when the wind is strong in the direction the automobile is running, is one of the later devices and a much-needed improvement.

THE FAN-COOLED MOTOR

In Fig. 219 is shown a fly-wheel fan consisting of light wings attached to the front face of a fly-wheel, and the wheel and fan encased to direct the air-blast directly on to the motor-head and cylinder air-cooling flanges. This system has been the subject of English experiments with the following results:

When enclosed in a suitable case, arranged to concentrate the whole blast on the engine, it took only $\frac{1}{20}$ of a horse-power at full speed, and gave a blast of 25 to 28 miles per hour. It kept the engine rather cooler than when running full speed on the road without the fan.

It is generally admitted that no air-cooled engine can work at full power continuously without overheating, except when running at a very high speed with a light weight on a level track, and

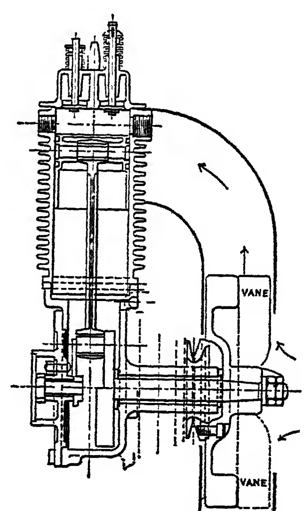


FIG. 219.—Motor-driven air-blast.

with a high gear suitable only for racing. Where such a machine is required to climb hills on a low or medium gear, some makers fit a little fan to stir the air around the head of the engine, but the majority are reverting to water-cooling as the only satisfactory method. It seems to be generally considered that the power wasted in driving the fan is greater than the power gained by more effective cooling. This misconception arises chiefly from inefficient methods of constructing the fan and applying the cooling blast. The fly-wheel fan absorbed so little power that it was very difficult to detect or measure the power absorbed. By employing a small electric motor to run the fly-wheel alone in its bearings (the piston and the rest of the engine gear being removed) with and without the fan attached, it appeared that the power absorbed at 2,000 revolutions did not exceed $\frac{1}{30}$ of a horse-power, which is quite negligible in comparison with other losses. This very small outlay of power, properly applied, makes all the difference, when carrying a load of five hundred weight up a long hill, between the motor overheating hopelessly and coming to a stop in the first half-mile, and racing up the whole three and a half miles at full throttle.

THE EXPLOSIVE-MOTOR CLUTCH

The clutch for facilitating the starting of explosive motors has become a most essential adjunct of every motor plant. The later designs are automatic in their action, and when once closed with the driven machinery increase their frictional resistance by automatic closure. The creeping of clutches, with its consequent loss of power and wear due to the impulse operation of the explosive motor, has been overcome and creeping is automatically arrested by increase of frictional pressure.

In Fig. 220 we illustrate a front view and in Fig. 221 a section of a pulley or gear-clutch of the Carruthers-Fithian type, as used on motors of from 5 to 35 horse-power.

The hand-wheel 8 locks the screw-sleeve 9 by pushing and turning the wheel in the direction that the motor is running, which pushes the cross-head 3 and the rack-bars in, revolving the gears 4 on right and left screws, which throw out the friction-shoes to contact with the friction rim. Then drawing the hand-wheel back

locks the wheel in the dentals of the nut and screw-sleeve, when the motion of the motor tightens up the friction automatically.

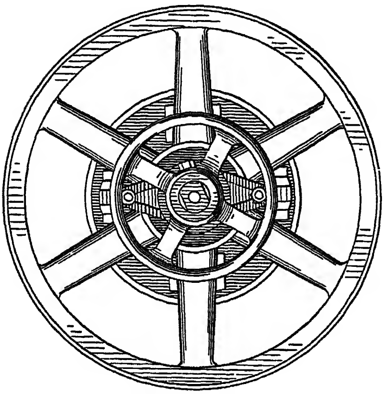


FIG. 220.—Front view of clutch.

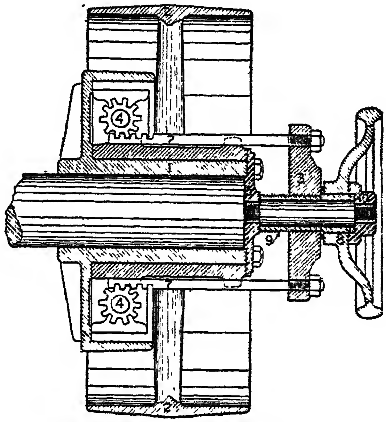


FIG. 221.—Section of clutch.

In Figs. 222 and 223 we illustrate their worm-gear clutch for the larger motors of from 40 to 150 horse-power. The operation of throwing the clutch in is much the same as with the smaller clutch, only that the transmission is through three spur-gears and worm-

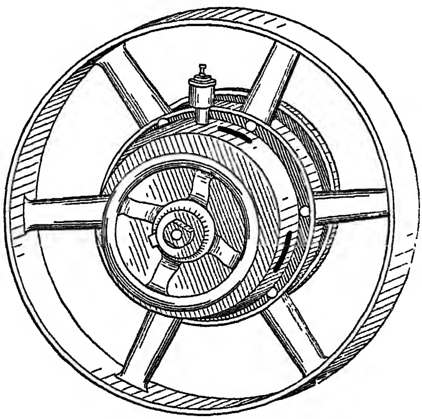


FIG. 222.—View, worm-gear clutch.

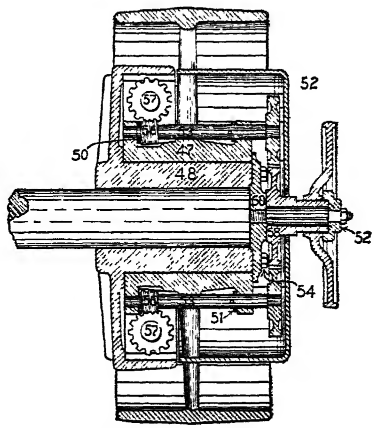


FIG. 223.—Section, worm-gear clutch.

gears on the right and left screws, which operate the friction-shoes with great power.

These clutches are made by the Carruthers-Fithian Clutch Company, Grove City, Pa.

In Fig. 224 is a section of the B and C gas-engine clutch, which consists of three main parts: the pulley, the carrier, which is bolted to the arms of the engine fly-wheel and acts as a journal of the pulley, and the gripping mechanism, which consists of a gripping plate, spindle, and cam-levers. The clutch has a side-grip which eliminates the effect of centrifugal force and insures a positive release.

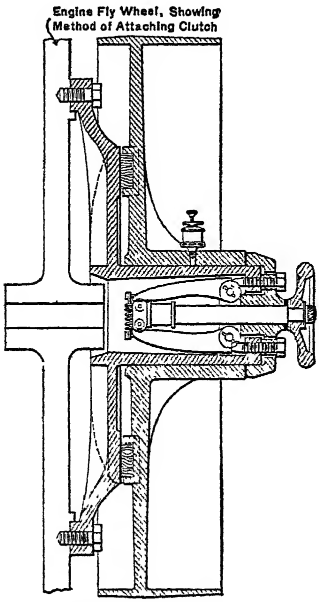


Fig. 224.—Gas-engine clutch.

Two rollers are mounted on the end of the spindle, which works in and out through a hole in the gripping plate, and journaled on the end is the operating hand-wheel, which can be held in the hand regardless of the speed of the engine. Bearing on the rollers are cam-levers, which in turn are pivoted on the gripping plate, and lugs on the levers abut against the adjusting screws. These adjusting screws go through a flange on the carrier, and are locked in place by lock-nuts, which also hold the gripping plate in position.

In the operation of the clutch, when the spindle is pulled out against the stop, the pulley is free to turn on the carrier-journal and when pushed in is gripped in a circular vise and turns with the engine fly-wheel. The load can be taken up as gradually as desired by pushing in the hand-wheel slowly, and released at will by pulling it out. Made by the Whitman Manufacturing Company, Garwood, N. J.

REVERSING GEAR FOR MARINE ENGINES

A five-spur gear-reversing clutch (Fig. 225) is much in use on marine engines in which the gears are constantly oiled by the dipping of the shaft gears in the oil-trough below. The gear on the

wheel-shaft is fixed to the shaft and driven for forward motion by a friction-clutch sleeve feathered on the end of the motor-shaft.

For reversing, the yoke-lever is thrown over and engages the feathered sleeve in the clutch of the idle gear on the motor-shaft, when the back-motion is transmitted through this reverse-gear train to the propeller-shaft. The clutches are of the expanding ring type. Made by the Michigan Motor Company, Grand Rapids, Mich.

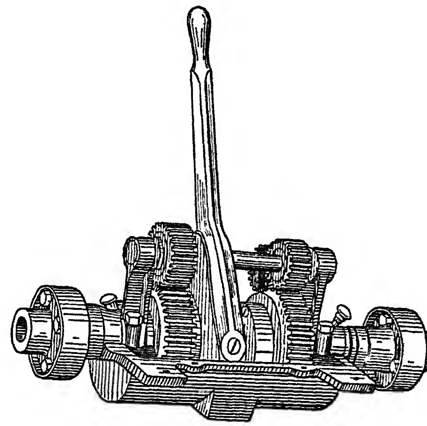


FIG. 225.—Reversing gear.

A simple and effective reversing gear for marine motors, made by the William H. Brodie Company, 45 Vesey Street, New York City, is illustrated in Fig. 226.

It consists of three bevel gears and a clutch-sleeve; the sleeve is on the motor-shaft with a traverse spline and friction-drive on the shaft bevel wheel.

The bevel wheel on the propeller-shaft is fixed to the shaft, while the bevel wheel on the motor-shaft runs loose.

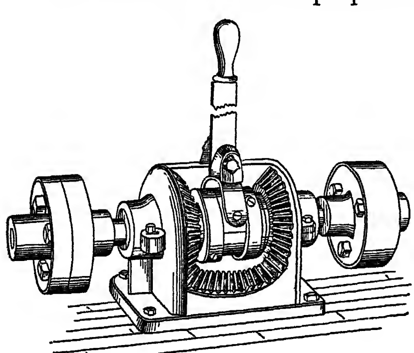


FIG. 226.—Brodie reversing gear.

The third bevel wheel runs on a pin fixed to the box-frame. When the lever is thrown forward the sleeve is thrust against the friction surface of the propeller gear and the other bevel gears run loose. When the lever is thrown to the centre all the gears are in repose. For the back motion of the propeller, the lever is thrown back and the sleeve engages the friction of the loose motor

gear and reverses the propeller through the action of the idler gear.

In Fig. 227 is shown a sectional detail of the Mietz and Weiss reversing friction-clutch as used on their marine oil-engines.

It consists of an oil-tight cast-iron drum made in two sections and is keyed to the shaft.

Inside of this drum is a steel stub-shaft on the inner end of which is keyed a friction-driving cone. There are two friction-disks with

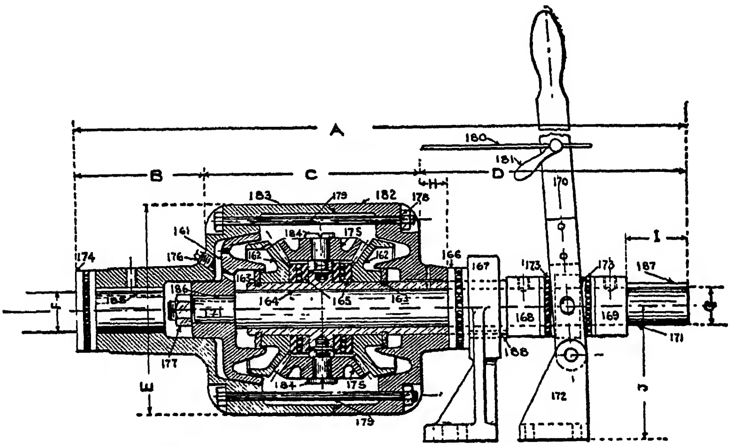


FIG. 227.—Mietz and Weiss reversing clutch.

beveled gears and interposed pinions on a bronze sleeve, which is prevented from rotating by a key in its bearing, screwed to the base of the engine. This bronze sleeve is free to slide longitudinally. The two friction-disk bevel gears rotate around this sleeve and are held in place by means of split-washers.

On the forward motion the stub-shaft, to which the propeller-shaft is coupled, is brought forward by means of the lever, and the friction-driving cone on its inner end engages the inner surface of the drum, imparting a forward motion direct from the engine-shaft to the propeller, the thrust of the propeller thus acting directly on the friction-cone and on the thrust-ball collar at the engine-bearing.

On the reverse, the lever is thrown back, thus releasing the forward thrust of the driving cone, and bringing its inner friction surface directly in contact with the friction surface of the first bevel

gear, while the second gear, engaging the inner friction of the drum, imparts through the interposed pinions a reversed motion to the stub-shaft and thence to the propeller.

A central position of the lever disengages the friction surface from the drum entirely, so that the engine may continue to run idle while the propeller is at rest.

The thrust of the propeller on the forward motion exerts its entire force directly against the friction surfaces, without the assistance of toggle-levers or cams, the whole connection from the engine to the propeller acting as one shaft. On the reverse, the tension of the propeller upon the shaft exerts its force against the reverse-gearing and inner-driving surface of the drum in the desired direction. The lever must be locked in its forward, central. or reversing position.

SPEED GEARS FOR AUTOMOBILES

Fig. 228 illustrates a speed gear of the Doris type. To the upper shaft are fastened three gears corresponding to the three pinions,

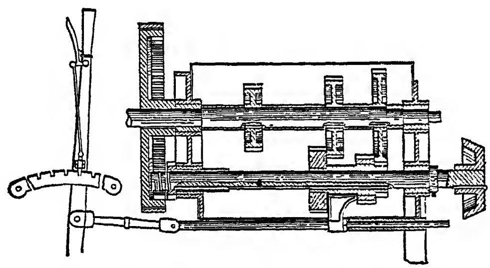


FIG. 228.—Automobile change-speed gear.

and in addition an internal gear outside the casing and of comparatively large diameter. A pinion is mounted upon the lower shaft, at the end thereof, adapted to mesh with the internal gear, but is normally held out of mesh by means of a coiled spring at the end of the shaft. The pinion is mounted upon a long sleeve surrounding the shaft and extending through the bearing into the casing. The set of three shifting pinions is shown in the position of slow forward speed. By moving them to the left the second and third speeds are engaged in succession, and after the gears of the third speed are out of mesh, if the motion is still continued, the sliding pinions will abut

against the sleeve of the reverse pinion, and shift the pinion into mesh with the internal gear against the pressure of the spring.

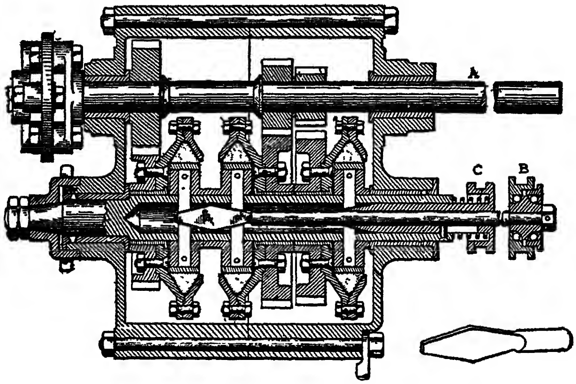


FIG. 229.—Automobile change-speed gear.

Fig. 229 illustrates a speed gear of the Petteler type—French—in which A is the driving shaft with fixed gears; B, collar on spear-

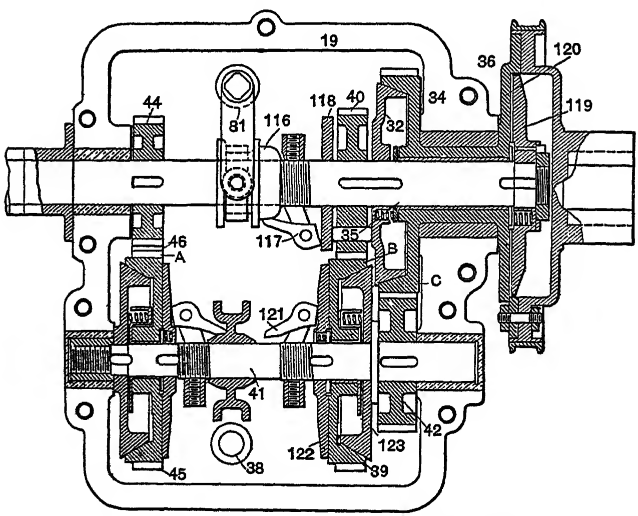


FIG. 230.—Winton automobile change-gear.

Reference Numbers: 19, gear-case; 81, high-speed shifting-yoke; 32, high-speed cone; 34, high-speed gear; 35, high-speed clutch-pin; 36 high-speed gear; 38, low and reverse-speed shifting-yoke; 39, low-speed gear; 40, low-speed pinion; 41, low and reverse-speed clutch-ball; 42, counter-shaft gear; 44, reverse-speed pinion; 45, reverse-speed gear; 46, reverse-speed idler-gear; not shown. 116, high-speed clutch-ball; 117, high-speed clutch-dog; 118, high-speed gear dog-plate; 119, high-speed friction-disk; 120, emergency-brake drum; 121, low-speed clutch-dog; 122, low-speed clutch-plate; 123, low-speed cone; A, reverse-gear combination with idler; B, low-speed gear combination; C, high-speed gear combination.

shaped blade-rod for operating the plungers for clutching the forward-motion gears; C, collar to a sliding conical sleeve that operates the plungers for the back motion through an idler gear, not shown.

In Fig. 230 is illustrated the change gear of the Winton automobile-motor, of which the sub-references indicate the parts which are operated by two shifting yokes controlling the speeds and reverse.

A novel starting device for small motors on runabouts or other light carriages, an English design, is shown in Fig. 231. A starting wheel B, with oblique saw-teeth, is fixed on the motor-shaft A. A sprocket chain C C′ is wound on a drum containing a coiled spring D, so arranged as to rewind the chain with a stop J, so as to allow it to hang free from the ratchet-wheel when the finger-loop at E is dropped to the eye in the vehicle floor. G is the sheave; K the slotted guide-plate; F the lanyard. To start, pull on E to catch the chain in the teeth of the wheel and with a jerk set the wheel revolving, and, if necessary, repeat.

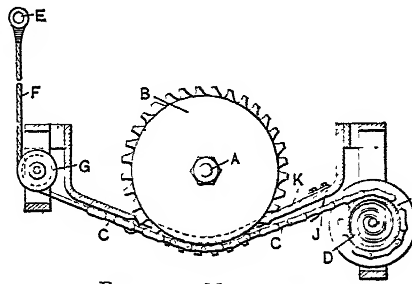


FIG. 231—Motor-starter.

AN AUTOMATIC FOOT-TREADLE

In Fig. 232 is shown a device for controlling the motor of an automobile, which is made by the Turner Brass Works, Chicago, Ill.

The great advantage claimed for this device is that it gives complete control of the two most vital parts of an automobile, viz., the spark and throttle on carbureter, by having automatic means of setting and holding either in any position, operating either one separately, or both simultaneously, as desired, with one foot.

This leaves both hands free for operating the wheel or clutch-lever and one foot for whatsoever duty it may be desired, such as for operating the brake.

In starting the motor, the carbureter throttle can be thrown wide open and held there by the ratchet, while the spark can be set to

just the point where practice and best judgment dictates it should be set to give the best chance of starting. It also gives one the advantage of being able to alter the speed while vehicle is standing and slow the motor down to any speed desired, while for checking the speed of a car no better or more efficient means could be devised than to throttle carbureter and retard the spark simultaneously, as can be done with this attachment by the simple operation of tilting the two pedals together. In starting the vehicle the carbureter can be first thrown on full and the spark advanced gradually to suit speed of motor. This device is easily applied, being self-contained. The lugs on treadle are sufficiently large to allow for pinning on shoes or extension-shafts, which can be carried to the opposite side of the automobile when occasion demands.

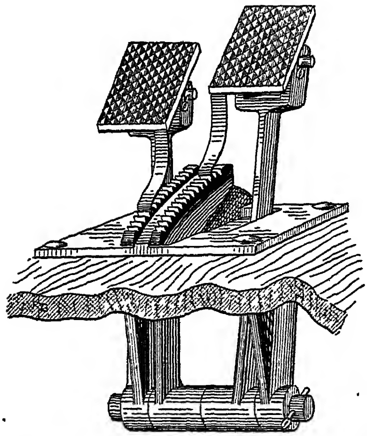


FIG. 232.—Automobile motor-controller.

In Fig. 233 is illustrated the safety device of the E. R. Thomas

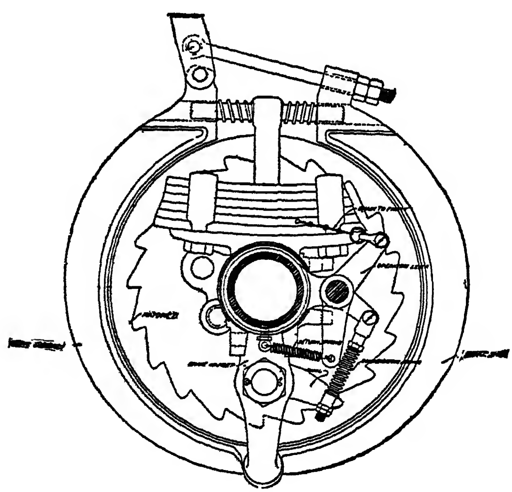


FIG. 233.—Safety automobile device.

Motor Company, Buffalo, N. Y., used for preventing automobiles from backing on uphill grades, should the motor stop from any cause. By its use the car cannot back on the steepest hill.

Every Thomas automobile is equipped with the Thomas safety device, a peculiar ratchet cast integral with the brake and sprocket-drum on the rear hubs, the co-acting pawl being pivoted to the brake-spider. It is operated by a hand lever on the right side of the dashboard to which the pawl is connected by a wire cable. This safety device positively prevents the car from backing downhill should the engine stop. It can be used in place of the brake when stopping on a hill. This makes the Thomas car particularly adapted for use in hilly sections, and renders accidents from backing an impossibility. It is one of their distinctive and exclusive features.

The devices for controlling the motion of vehicle-motors and the speed of automobiles are most numerous, and to which many pages might be devoted, perhaps without furthering the object of this work, which is naturally confined to the principles and construction of the explosive motor alone; yet there are so many points in the application and use of this novel power, so many adjuncts required in its successful adaptation for all purposes, that their illustration seems necessary in order to extend such details for the satisfaction of the inquiring reader.

The application of this new power to, and its development of high speed in automobiles, racing boats, and for direct-connected electric-generating power, depending, as it does, upon the highest designing and constructive art, has made a marvellous progress during the past few years.

Although we have endeavored to bring out in this work, by illustration and description, the most essential features of the explosive motor and its adjuncts, there is still a large field open for development of economy in design and construction, while the field of invention is not yet near exhaustion.

Its many points of advantage in power for vehicle and launch-service will no doubt make it the leading type in the future for this particular service.

CHAPTER XVII

THE MEASUREMENT OF POWER

THE methods of measuring power are of but two general forms or principles, although the individual machines or instruments for accomplishing the measurement are of many kinds and of a variety of construction.

The one form is especially adapted for the measurement of the available power of prime movers under the various conditions of the application of their elementary power constituents, by the absorption of their whole output of power at the point of delivery and there record the value of its force and velocity. Its representative is the brake-dynamometer, or Prony's brake, in the various details of construction that it has assumed as designed and applied to meet the views or fancies of mechanical engineers.

The second form is a marked departure from the structural form of the first, and with the principle in view of placing as little obstruction as possible to the transmission of power from the prime mover to the receiver of power, to measure the actual net or differential tension of a belt or gear, and with its velocity indicate the exact amount of power delivered to a line of shafting or a machine. These are called transmitting dynamometers in distinction from the absorption dynamometers of the Prony type. They are of two kinds, one with a dial and index-pointer, by which the hand on the dial must be constantly watched and recorded for a length of time and a mean pressure obtained from the varying record. The other carries a self-marking register moved by clockwork, by which the actual pressure is a constant record for any desired time, or a full day's work, the only personal observation required being the speed of the pulley or belt or its average throughout the time or day.

In Fig. 234 we illustrate the first form, a simple absorption dynamometer or Prony's brake, named after its inventor, in which A is the radius of the pulley-drum or shaft to which resistance may

be applied; B, the length of the lever from the centre of the shaft to the point of attachment of the spring scale or other means of measuring the tension of the lever; C, a spring scale, which is pref-

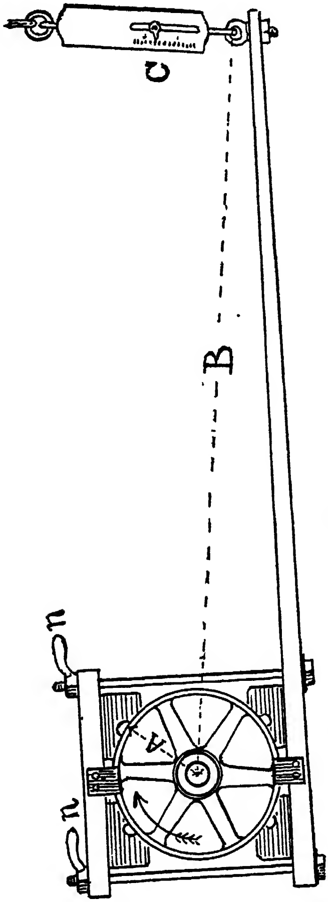


Fig. 234.—The Prony brake.

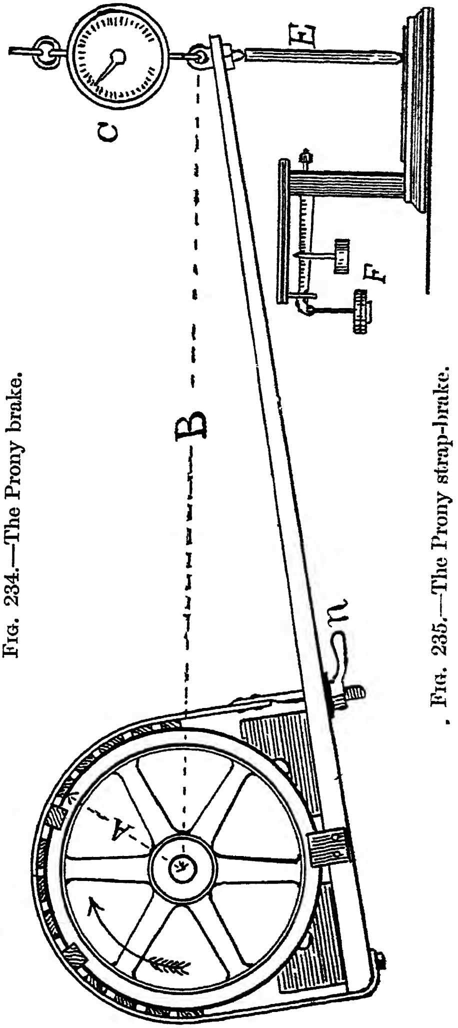


Fig. 235.—The Prony strap-brake.

erable for light work within its range; and N N, lever-nuts for quick control of the pressure.

In Fig. 235 is presented a simple and inexpensive arrangement

of a power-absorbing brake for a large driving pulley or finished fly-wheel, in which a belt is lined with blocks of wood spaced and fastened to the belt with screws or nails, a few of the blocks projecting over the edge with shoulders to prevent the belt from running off the pulley.

Spring scales may be purchased of the straight and dial pattern up to one or two hundred pounds capacity at reasonable figures, and are a source of satisfaction in showing the amount of vibration due to irregular pulsations of the motive element and crank motion. Where the measurement of power beyond the range of a spring balance is required, the use of a platform scale or any other weighing device may be made available. With a platform scale the light wooden strut E (Fig. 235) may be adjusted to any length of lever, vertically reaching from the platform to the horizon line B, from the centre of the shaft; lanyards or any convenient means being used to keep the end of the lever from swaying.

Water from a squirt-can is the best lubricant for this class of dynamometers, as it can be easily thrown upon the face of the pulley at the interstices of the blocks and lagging, and by its quick evaporation carries off the heat generated by friction. Soapy water has been used to good effect in preventing irregular pressure or stickiness of the friction surfaces.

It matters not in what direction the brake-lever is placed to suit the convenience of observation, so long as the pull of the scale is made at right angles to the radial line from the shaft centre. Its weight, as indicated on the scale, with the friction-blocks or strap loosened in any position that it may be set, should be noted and a record made of the amount, which must be deducted from the total observed weight of the trial. If it is necessary to reverse the position of the lever or the relative direction of the motion of the pulley (as shown in Figs. 234 and 235), then the weight of the lever must be added to the weight shown by the scale under trial. When the platform scale is used the weight of the lever must necessarily be downward and should be deducted from the weight shown by the scale under trial. Making D equal the diameter of the face of the pulley, fly-wheel, or shaft upon which friction is applied, in feet or decimals of a foot, B the length of the lever from the centre of the shaft to the point of the scale suspension, A the radius of the

pulley fly-wheel, or shaft, also in feet or decimals of a foot, and R the number of revolutions of the shaft per minute: the weight used in the formula must be the net weight of the power stress, or the gross observed weight less the weight of the lever. Then

$$\frac{D \times 3.1416 \times R \times \frac{B}{A} \times \text{weight}}{33{,}000} = \text{horse-power},$$

$$\text{or } \frac{B \times 6.2832 \times R \times W}{33{,}000} = \text{horse-power}.$$

$\frac{B}{A} \times$ weight = the stress or pull at the face of the pulley, and $D \times 3.1416 \times R$ = the velocity of the face of the pulley or of the belt that it is to carry.

In Fig. 236 is represented a simple and easily arranged differential strap-brake or dynamometer for small motors of less than two horse-power. It consists of a piece of belting held in place on the pulley by clips or only strings fastened parallel with the shaft to keep the belt from slipping off; two spring scales, one of which is

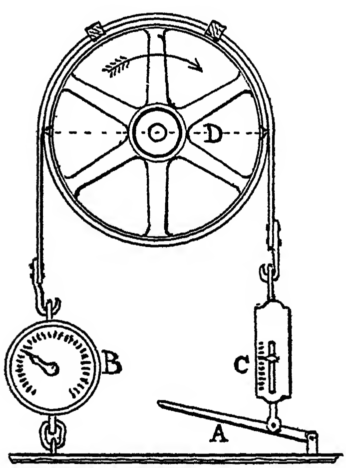


Fig. 236.—Differential strap-brake.

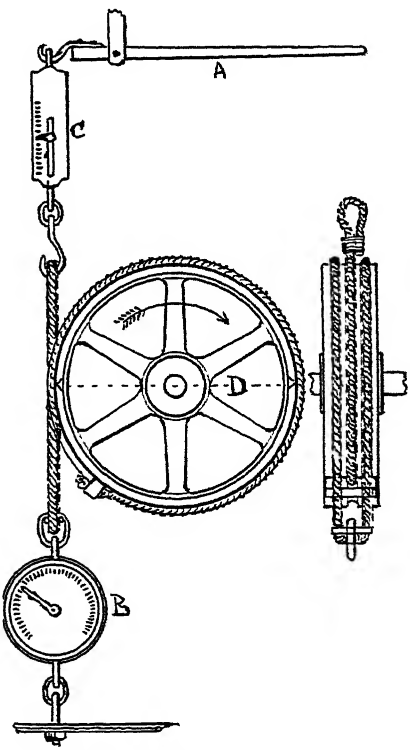


Fig. 237.—Differential rope-brake.

anchored and the other attached to a hand-lever to regulate the compression of the belt upon the surface of the pulley, when the differential weight B − C on the scales may be noted simultaneously with the revolutions of the pulley. The simple formula

$$\frac{D\times 3.1416\times R\times \text{differential weight}}{33{,}000}=\text{horse-power.}$$

Fig. 237 illustrates a rope-absorption dynamometer or brake with a complete wrap on the surface of the pulley, very suitable for grooved pulleys or fly-wheels used for rope-transmission. In this form the friction tension may be regulated with a lever as at A. The weight W in the formula is the differential of the opposite tensions of the two scales, or B − C = W (Fig. 237), and the formula will then be: $\frac{D\times 3.1416\times R\times W}{33{,}000}=$horse-power, as in the notation (Fig. 236).

Thus it may readily be seen that the difference of the pull in a rope or belt on the two sides of a pulley, multiplied by the velocity of the rim in feet per minute, and the product divided by 33,000, gives the horse-power either absorbed or transmitted by the rope.

THE MEASUREMENT OF SPEED

The revolutions of a motor may be readily obtained by an ordinary hand-counter, with watch in hand to mark the time; but for accurate work and to show the variations in the fly-wheel speed by the intervals of revolution between impulses, and especially the effect of mischarges or impulses due to governing the speed, there is no more accurate method than by the use of the centrifugal counter or tachometer.

These instruments are designed to show at a glance a continuous indication of the actual speed and its variation within 2 per cent. by careful handling of the instrument. The tachometer (Fig. 238), with a single-dial scale three inches in diameter, reads from 100 to 1,000 revolutions per minute, and by changing the gear for the range of gas-engine indication the actual revolutions will be one-half the indicated revolutions, which divided by 2 will represent the actual speed. In this manner a very delicate reading of

the variation in speed may be obtained. For testing the variation of speed in electric-lighting plants operated by gas, gasoline, or oil-engines, there is no method so satisfactory as by the use of the tachometer.

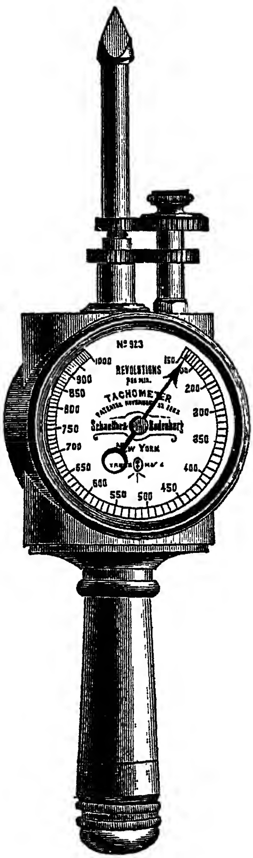


FIG. 238.—The tachometer.

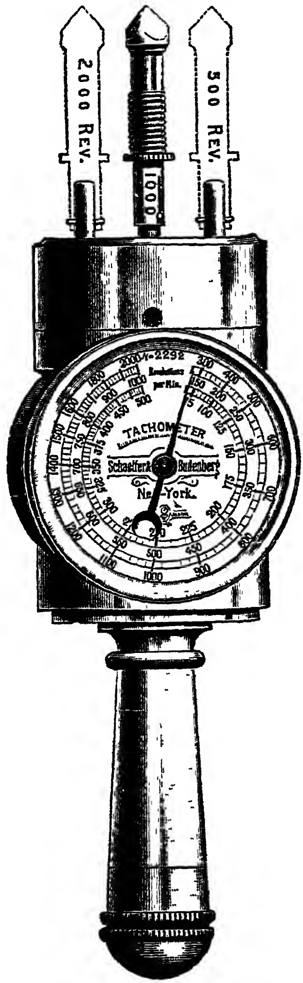


FIG. 239.—The triple-indexed tachometer.

The triple-indexed tachometer (Fig. 239) is a most convenient instrument for quickly testing and comparing speed of great differ-

ences, as the motor and the generator, by simply changing the driving point from one to another gear stem. These tachometers are made by Schaeffer and Budenberg, New York, and may be ordered for any range of speed, from 50 to 500 for gas-engines and from 500 to 2,000 for generators, in the same instrument or separate as desired.

THE INDICATOR AND ITS WORK

We have selected among the many good indicators in the market the one most suitable for indicating the work of the explosive en-

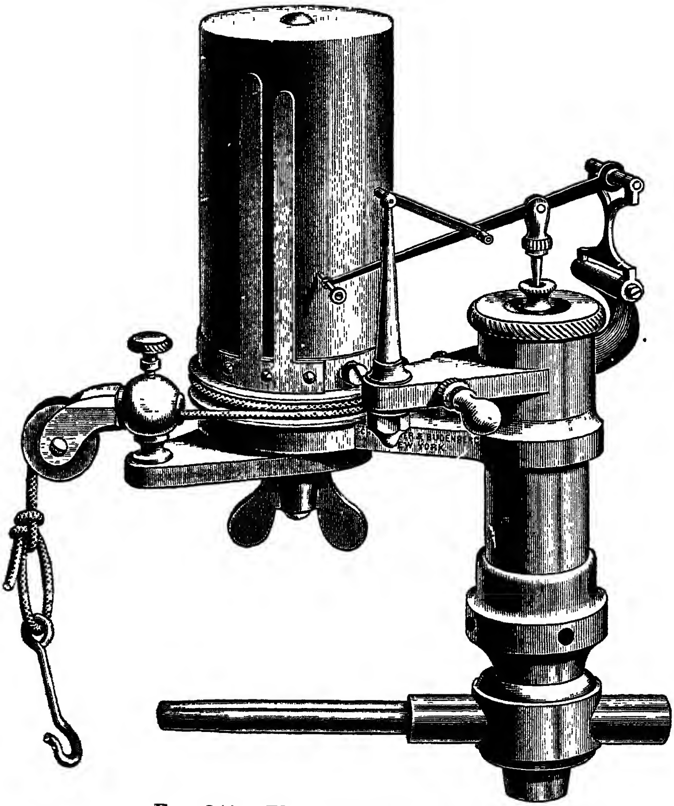


Fig. 240.—The Thompson indicator.

gine. The Thompson indicator as made by Schaeffer and Budenberg, New York, and illustrated in Figs. 240 and 241, is a light and sensitive instrument with absolute rectilinear motion of the pencil,

with its cylinder and piston made of a specially hard alloy which prevents the possibility of surface abrasion and insures a uniform frictionless motion of the piston. It is provided with an extra and smaller-sized cylinder and piston, suitable with a light spring for

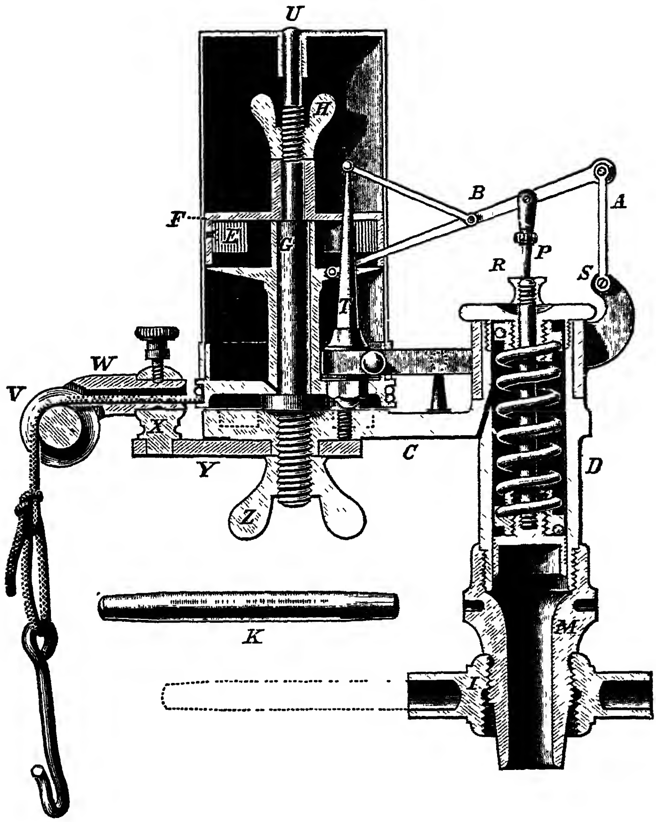


FIG. 241.—Section of indicator.

testing the suction and exhaust curves of explosive motors, so useful in showing the condition and proportion of valve ports.

The large piston of the standard size is 0.798 inch in diameter and equal to ½ square-inch area. The small piston (Fig. 242) is 0.590 inch in diameter and equal to 0.274 square-inch area, so that a 50 or 60 spring may be used in indicating explosive engines with the small piston, which will give cards within the range of the

paper for low-explosive pressure but full enough to show the variations in all the lines. With the 100 spring and ½-inch area of piston 250 pounds pressure is about the limit of the card, but with this size piston a 120 or 160 spring is more generally used.

The pulley V is carried by the swivel W, and works freely in the post X; it can be locked in any position by the small set screw. The swivel-plate Y can be swung in any direction in its plane and held firmly by the thumb-screw Z. Thus with the

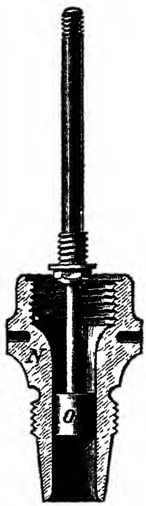


Fig. 242.—Small piston.

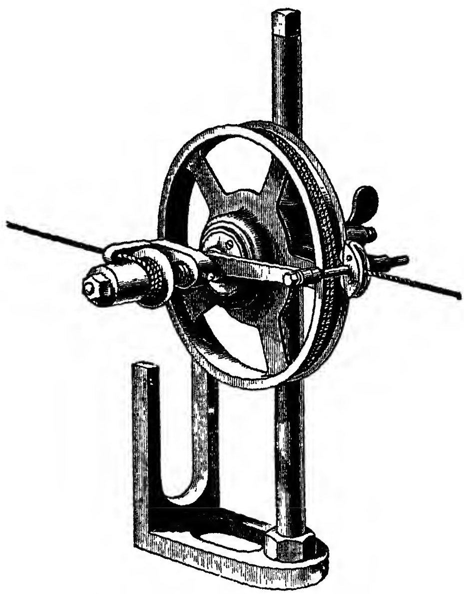


Fig. 243.—The reducing pulley.

combination the cord can be directed in all possible directions. The link A is made as short as possible, with long double bearings at both ends to give a firm and steady support to the lever B, making it less liable to cause irregularities in the diagram when indicating high-speed motors.

The paper drum is made with a closed top to preserve its accurate cylindrical form, and the top, having a journal-bearing at U in the centre, compels a true concentric movement to its surface.

The spring E, and the spring-case F, are secured to the rod

G by screwing the case F to a shoulder on G by means of a thumb-screw H.

To adjust the tension of the drum-spring, the drum can be easily removed, and by holding on to the spring-case E, and loosening screw H, the tension can readily be varied and adapted to any speed, to follow precisely the motion of the engine-piston.

The bars of the nut I are made hollow, so as to insert a small short rod, K, which is a great convenience in unscrewing the indicator when hot.

The reducing pulley (Fig. 243) is a most important adjunct of the indicator. The revolving parts should be as light as possible and are now made of aluminum for high-speed motors, with pulleys proportioned for short-stroke motors. In the use of indicators for high-compression motors it is advisable to have a stop-tube inserted in the cap-piece that holds the spring and extending down and inside the spring so as to stop the motion of the piston at the limit of the pencil motion below the top of the card. This will prevent undue stress on the spring and extreme throw of the pencil when, by misfires, an unusual charge is fired. With the smaller piston and the usual 100 or 120 spring any possible explosive pressure may be properly recorded.

The proximity of the indicator to the combustion chamber is of importance in making a true record of the explosive action of the combustible gases on the card. The time of transmission of the wave of compression and expansion through a tube of one, two, or three feet in length is quite noticeable in the distortion of the diagram. It shows a delay in compression and carries the expansion line over a curve at the apex lower than the maximum pressure, and by the delay raises the expansion curve higher than the actual expansion curve of the cylinder. An indicator for true effect should have a straightway cock screwed into the cylinder.

VIBRATION OF BUILDINGS AND FLOORS BY THE RUNNING OF EXPLOSIVE MOTORS

Since this class of engines has so largely superseded small steam-power, and the vast extension of their use in the upper part of buildings due to their economy for all small powers, the trouble

arising from the vibration of buildings and floors by their running has largely increased.

The necessity for placing motive power near its point of application has resulted in locating gas, gasoline, and oil-engines in light and fragile buildings and on floors not capable of resisting the slightest synchronal motion.

This subject has been often brought to our notice since the advent of the gas-engine in the lead for small powers. It is a difficult question to advise remedies for it, from the variety of ways in which the effect is produced. Synchronism between the time vibration of a floor and the number of revolutions of the engine is always a matter of experiment, and can only be ascertained by a trial in varying the engine speed by uniform stages until the vibration has become a minimum. Then if the engine speed of least vibration is an inconvenient one for engine economy, or for the speed layout of the machinery plant, a change may be made in the time vibration of the floor by loading or bracing. The placing of a large stone or iron slab under a motor will often modify the intensity of the vibration by so changing the synchronism of the floor and engine as to enable the proper speed to be made with the least vibration.

A vertical post under the engine is of little use unless it extends to a solid foundation on the ground; nor should a vertical post be placed between the engine-floor and floor-beams above, as it only communicates the vibrations to any floor in unison with the vibrations of the engine-floor.

A system of diagonal posts extending from near the centre of a vibrating floor to a point near the walls or supporting columns of the floors above or below, or a pair of iron suspenders placed diagonally from the overhead beams near their wall bearings to a point near the location of an engine and strongly bolted to the floor-beams, will greatly modify the vibration and in many cases abate a nuisance.

In the installation of reciprocating machinery on the upper floors of a building in which the reciprocating parts of the motor, as a horizontal engine, are in the same direction as the reciprocating parts of the machines (as in printing press-rooms) the trouble from the horizontal vibration has been often found a serious one. It

may be somewhat modified by making the number of the strokes of the engine an odd number of the strokes of the reciprocating parts of the machine.

It is well known to engine-builders that explosive motors, like high-speed steam-engines, cannot be absolutely balanced, but their heavy fly-wheels and bases go far toward it by absorption, and the best that can be done with the balance is to make as perfect a compromise of the values of the longitudinal and lateral forces as possible by inequality in the fly-wheel rims.

The jar caused by excessive explosions after misfires and muffler-pot explosions is of the unusual kind that cannot be easily provided with a remedy where the transmitted power is not uniform, for where it is uniform there is ample regulation from the governor to make the charges regular, and if the igniter is well adjusted there should be no cause for "kicking," as our European cousins call it. A good practice in setting motors is to locate them near a beam-bearing wall or column that extends to the foundation of the building. Many motors so placed are found to be free from the nuisance of tremor.

The duplication of cylinders and the definite counter-balancing now in use has, in a great measure, modified these troubles and two and three-cylinder motors are in great favor where only unstable foundations are available.

CHAPTER XVIII

ON THE MANAGEMENT OF EXPLOSIVE MOTORS

THE drift of constructive practice in the United States seems generally to be in the line of simplicity and least number of parts, in order to conform to the needs of the people that have the care of such motive power. The explosive motor now appeals to no experience as an engineer for its care and running; yet it does seem to require some common sense as to cleanliness and the propriety of things that may assume a menacing or dangerous habit by neglect of some of the few points of attention required in persons having the charge of this rising prime mover. The ability to discover leakage of gas or oil-vapors or the products of combustion in the pipe connections, through valves, or by a defective or worn piston; the thumping in journal-boxes, looseness of pins, and piston thump is easily acquired when a person assumes the care of an engine. The regulation of the explosive mixtures is fully explained in the instruction pamphlets and display sheets of the builders, and from the completeness of instructions furnished there seems nothing to fear in the first start of an explosive motor by any person of ordinary intelligence.

Cleanliness being of the first order, due attention should be given to the cleaning of the cylinder, valves, and exhaust-pipe at stated intervals; in some motors at least once a month, in other motors several months may elapse without internal cleaning being necessary, apparently without detriment. But we apprehend that the quality of the fuel has much to do with the fouling of the combustion chamber and exhaust-pipe, and therefore the quality of the fuel should be suggestive of the times indicated for internal cleaning. Excessive use of fuel or a too rich mixture is the cause of many mysterious troubles, especially in motors using the heavier oils, as with kerosene, distillate, and crude petroleum containing a large percentage of carbon, which is not burned and becomes pre-

cipitated on the interior walls of the motor and the exhaust-pipe. The outside surfaces should be wiped off before starting or at the close of work every day, especially where the location is in a room with working people, as the odor of the lubricating oil is not agreeable when the oil is spread in excess over an engine.

In workshops or rooms where dust prevails it is most desirable to enclose the motor in a small room by itself, well ventilated from without, for motor cylinders are mostly open and gather dust on their oily surfaces, and dust in the in-going air of combustion leaves grit and ashes in the cylinder. The oil for lubricating the cylinder should be the best "cylinder-oil" of the trade, and is sold by many dealers as "gas-engine cylinder-oil." It is not so expensive as to preclude its use for all the moving parts of an explosive motor, although a poorer quality is in general use.

Automatic oil-feeders are almost universally furnished with these engines, so that there should be very little waste of oil. In cleaning the internal parts from carbon and oil crust, no sharp scrapers should be used on any rubbing parts or the bearing of valves. If unable to remove the crust with a cloth and kerosene oil, a hard-wood stick and oil will generally remove the incrustation down to the metal, while the valves, if not cut, only need rubbing on their seats with finely pulverized pumice or other polishing powder. Emery is not recommended, as valves often get too much grinding to their detriment by the use of this material.

In starting a motor it should always be turned over in its running direction, and when compression makes this difficult the relief-valve (most motors have one) or the exhaust or air-valve may be opened to clear the cylinder, if an overcharge of gas or a failure has been made at the first turn.

In most cases turning the fly-wheel two or three revolutions will clear and charge the cylinder under the usual conditions for starting. With most of the large motors a starting device is provided, which is described in the special exhibit of the explosive motors further on.

Some of the troubles to be met are severe explosions after several misfires, by which the cylinder may become overcharged with the combustible mixture. This is often caused by irregular work on the engine, and the consequent scavengering of the cylinder of

the products of previous explosions, replacing with pure mixtures at the next charge. Again, by a misfire from failure in the igniter an explosive charge is intensified at the next ignition or exploded in the exhaust-pipe. Other interruptions sometimes occur, such as the sticking of the exhaust-valve open by gumming of the spindle or a weak spring. From this may also arise some of the back-firings in the muffler and exhaust-pipe. All of these explosions taking place at irregular times may be attributed, first, to irregular work; second, to irregularity in the operation of the valve gear or igniter, and although not pleasant to the ear may not be considered dangerous, because the motors and all their parts subject to explosion are made equal in working strength to the greatest pressure made by such explosions.

With the compression usual in motors, 40 to 60 pounds, the greatest force from misfire or back-fire explosives can scarcely reach 300 pounds per square inch in the cylinders and 150 pounds in the mufflers, unless, by a possible contraction of the exhaust-pipe by carbon deposit, a muffler-pot may have possibilities of rupture. In no case should an exhaust-pipe be turned into a chimney. With gas-engines the full power is sometimes not realized from insufficient gas supply. The gas bag is a good indicator of this condition, caused by a too small gas-pipe or a small meter, by which a flabby appearance of the gas bag shows that the motor is drawing more than the pipe or meter can supply with a proper working pressure.

The muffler-pots have been known to accumulate water in cold weather, by condensation of the water vapor formed by the union of the hydrogen and oxygen of the gas and air, to such an extent as sometimes to cause fear in an attendant of a cracked cylinder and leakage of water in from the jacket circulation.

The water should be drawn off occasionally from the muffler-pot by a cock. Gas-motors running with electric igniters sometimes do not start at first trial from the accumulation of air in the gas-pipe. Testing by a gas-burner or a second trial will show where the difficulty lies and its remedy. And, finally, much caution should be observed in examining the interior of valve chambers and the electric exploders by taking off caps or plugs and using a light near them until assured that fuel-inlets are closed and the motor has been turned over several times to clear it of all explosive mixture. The

consequences of explosion from peep-holes are obvious. Even when a motor has been idle for a time it should be opened with the above caution.

The adjustment of governors requires only care and a careful study of the directions for operating the engines, as there are too many variations in the designs and methods of adjustment for definite instructions under this head. Much care is required in renewing the ignition-tubes, especially after the spare tubes furnished with the engine have been all used. The same size gas-pipe and of the same length as the tubes furnished with the engine should be made and the end welded up or capped, so that they may contain the same volume as the original tubes. This caution will ensure the uniform adjustment of the time of ignition by change of tubes: otherwise tinkering with the position of the Bunsen burner will not enable an attendant not experienced in regulating the time of ignition to regulate it with any degree of certainty. The regulation when once lost can be properly tested only by an indicator card.

With a timing valve and the amount of lead for the return fire from the tube being known, the adjustment of the timing-valve throw can be made from the position of the dead centre of the crank at the end of the forward stroke. The timing lead is the time that is required for the mixture to pass the valve and become compressed in the igniting tube and the flame to return to the combustion chamber, as measured on the circumference of the timing-valve cam.

Other than iron tubes are used, such as nickel-steel, aluminum, bronze, and porcelain, with satisfactory results. The porcelain tubes are made short and require a special fitting to adapt them to a chimney, or the chimney should be of special design (as shown in Fig. 68), for a cross impact of the flame of the Bunsen burner.

There are many points in the management of explosive motors that cannot be discussed in a general treatise, arising from the varied details of design, in which special reference to the methods of operating the valve gears of igniters and governors of each individual design is required. The special instructions furnished by builders are ample for the operation of their motors, and if carefully studied lead to success in their operation by any person of ordinary intelligence or tact in handling moving machinery.

Recent experience with gas, gasoline, and oil-vapor engines has brought out more strongly the good qualities of well-made explosive motors, and placed them far ahead as a reliable, cheap, and easily managed motive power, even up to many hundred horsepower in a single installation. The application of power from explosive motors for the generation of electricity for lighting and the transmission of power is no longer a mooted point of economy, but has become a fixed principle in the application of prime-moving power. The governing devices have been improved and applied in the line of uniform motion from intermittent impulse. An electric gas-governing device for controlling the flow of gas to correspond with the required amperage is a new governing application that seems to break the last objection to the use of explosive motors for generating the electric current for lighting purposes.

The hot-tube ignition seems to hold its own with increased life by the use of the nickel alloy and porcelain tubes as described in the article on Hot Tubes; for, while the electric spark has its advantages in many respects, it has likewise a few annoyances. When the spark or ignition fails, much detention may follow the search for the fault. The hidden contact-points, fouling of sparking insulation, battery faults and connections are to be looked after; or if a generator is used, the chances for faults in a constant-current generator are no less, but also become a cause of watchfulness.

The alternating generator is now coming into use for furnishing the igniting current with prospects of an exactitude so long desired, and to obviate some of the exigencies of the controlling mechanism in the continuous-current system.

As it is now well known that the full firing of an explosive charge is not instantaneous from the moment of igniton in the hot tube, and that the greatest mean pressure on the piston results from perfect ignition of the whole charge at the moment of the passage of the crank over the centre, it becomes a matter of considerable importance that the hot tube and Bunsen burner should be adjusted so as to allow the compressed fresh charge to reach the part of the hot tube at which the temperature is high enough to cause ignition of the charge at a moment just before the crank reaches its centre. The variable mixture of the charge, either from misfiring of a previous charge or from the action of an over-sensitive governor, has

made this adjustment heretofore somewhat difficult, especially where short-lived tubes were in use, for a change of tube usually varies the moment of ignition. Since the advent of the nickel alloy and porcelain tubes this difficulty has been greatly overcome, and the ignition tube has been restored to favor with many engine-builders who had adopted the electric system for its positive timing. The marine and automobile-engines, however, will probably hold to electric ignition from the obvious difficulty in managing a gasoline burner for such service.

Many minor improvements of the past year have conduced to a general economy in running expense and to ease of management, among which may be noted a device on the White and Middleton and other engines, by the turning of which the time of sparking is retarded at starting, and the engine prevented from the possibility of starting backward by explosion before the crank reaches the centre.

In this device the sparking push-blade has a double trip swiveled on the push-rod, the turning over of which changes the time of ignition.

The use of a generator armature revolving within the sphere of a permanent magnet, and operated from a contact on the flywheel of the motor to a pinion on the armature, is in use on a large number of motors and is well adapted to the marine and automobile types. It is growing in favor, and appears from inspection to be a reliable and satisfactory device.

In trials of gasoline-engines with gas-engines of the same size and construction, it has been found that the indicated horse-power from gasoline is from 12 to 20 per cent. higher than from illuminating gas, when running at full power. This does not correspond with the assigned number of heat units per cubic foot of gasoline-vapor and illuminating gas; for gasoline-vapor has been credited with almost the same value in heat units with 16-candle-power illuminating gas. The excessive power of gasoline-vapor is probably due to modern methods in the manufacture of illuminating gas, by which a large percentage of non-combustible element is produced in the form of carbon dioxide and nitrogen.

These elements of non-combustion exist to a very large extent in producer and water-gas, which is well known to require a

much larger engine for equal power with a high illuminating-gas or gasoline-engine. There is a tendency toward increase of compression to near its greatest theoretical economy, and engines are now in use with compression of 90 or more pounds per square inch, and with a clearance of 25 per cent., or less, of the space swept by the piston, with claims of from 14 to 12 cubic feet of illuminating gas per indicated horse-power per hour.

POINTERS ON EXPLOSIVE MOTORS

The explosive motor now appeals to no experience and responsibility of a professional engineer for its care and running, yet it does require much common-sense as to cleanliness and the propriety of things that may assume a menacing or dangerous habit by neglect of some of the few points of attention absolutely essential.

The ability to discover and locate leakage of gas or oil-vapors, or the products of combustion in the pipe connections, through valves or by a defective or worn piston; the thumping in journals, looseness of pins, and piston thump, is easily acquired when a person assumes the care of an explosive motor. The regulation of the explosive mixtures is so fully explained in the instructions now sent out with the motors that there seems nothing to fear in their first starting by any person of ordinary intelligence.

In the operation of these motors, cleanliness is of the first order, and due attention should be given to the cleaning of the cylinder, valves, and exhaust-pipe at stated intervals, according to the kind of fuel used. The highly carbonaceous gases and vapors require more attention in internal cleaning than those containing an excess of hydrogen and nitrogen constituent.

In using highly carbonaceous gases and vapors, cylinders, valves, and exhaust-pipes need cleaning at least once a month, while with the cleaner fuels, several months may elapse without cleaning.

The outer surfaces, boxes, and parts bespattered with oil should be kept clean, as well as the floor, which should have a zinc lining around the motor. Wiping up twice a day is none too much for cleanliness and the welfare of people working in the same room with a motor.

It is better to enclose the motor in a small room by itself, well

ventilated from without; it keeps dust from the cylinder and foul odors from the workrooms. It pays to use the best cylinder-oil for all parts of a motor, as it requires less of the good oil than of the poor quality for lubricating any surface and is inducive of efficiency. In cleaning the internal parts, avoid the use of a sharp scraper on rubbing surfaces and valve seats. A hard-wood stick and kerosene oil will generally do this work and save much after-trouble.

For regrinding valves, emery should not be used; pulverized pumice-stone and oil do the work well without overgrinding.

Some of the troubles met with in the operation of explosive motors are severe explosions after one or several misfires, by which the cylinder becomes overcharged with combustible mixture and on firing produces an excessive explosion and kick in the motor. This is due to irregular work of the motor or misfiring of the igniter. Other interruptions sometimes occur, such as the sticking of the exhaust-valve open by gumming of the spindle. From this may also arise the back-firing in the muffler-pot and exhaust-pipe, which, although not pleasant to the ear, is not considered dangerous, because the motors and all their parts subject to this explosive force are made equal in working strength to the greatest pressure from such explosions.

One possible evil is the rupture of a weak muffler-pot from the choking of the exhaust-pipe by soot—a suggestion to make the exhaust-pipe from the muffler-pot two pipe sizes larger than the usually assigned size for the motor.

In examining the interior of an explosive motor, care should be taken to remove any gas or vapor from all chambers and recesses by closing their inlets and turning over the fly-wheel several times with the air-inlet open. This is most essential for safety in removing plugs for examining the sparking electrodes. A few accidents have happened when looking at the sparking device through a plug-hole.

An accumulation of air in the gas-pipe is sometimes the cause of failure in starting with an electric igniter, and often attributed to the failure of the spark. A search in both directions will find the true cause of failure.

On purchasing a motor, the one who is to operate it should carefully study the mechanism and the instructions, as the detail in

operating the three kinds of fuel—gas, gasoline, and kerosene or crude oil—vary enough to require special inquiry for the operation of each kind.

The method of ignition is also peculiar and requires special instruction in either of the kinds of devices by which the motor is operated. Whether tube, hammer-spark, or jump-spark is selected, they are each so different in detail as to need special instruction.

One of the annoyances in explosive-motor service is the incrustation of the water-jacket by lime. Hard water, or such as contains a considerable amount of carbonate or sulphate of lime, when used as a free-running stream, has been found to choke a water-jacket in a few months so as to render the jacket almost useless as a cooling device. To obviate this difficulty a cooling tank of about twenty gallons per horse-power should be used, set above the cylinder and of such a form as to give large surface to the air, with a free circulation on all sides. A round tank gives the least air-cooling surface, while a long tank of galvanized sheet-iron with vertical corrugated sides has given the most satisfactory service.

By the use of a cooling tank charged with the best water attainable, preferably rain-water, and a pound of caustic soda to each five gallons, an encrusted jacket can soon be cleaned, or the incrustation so loosened that it can be easily scraped and washed out through the core openings. Acid and water has been recommended and used; but such treatment is not as convenient as the soda-circulation.

The manufacturer, if he understands his interests, usually furnishes sufficient explanatory matter to enable the operator to understand all details. Often this has been a failure, to the detriment of both maker and purchaser; but if the seller thinks he can afford to be careless about this, the buyer need not, for all shut-downs and interruptions caused by failure to operate a motor satisfactorily are more or less expensive.

For preventing the freezing of the water in the jacket or cooling tank in winter there is probably nothing better than a five per cent. addition of glycerine or a few pounds of chloride of calcium to the water of the cooling tank will prevent solid freezing in the coldest weather. For engines exposed to outside weather, ten per cent. glycerine may be used.

Finally, in starting a gas or gasoline-engine, it is well to remember a few facts in regard to the explosive qualities of the gas or gasoline-mixture. It has been shown in other parts of this work that the proportions of gas or gasoline and air have their limits for explosive effect and that too much or too little of the fuel element is non-explosive. This is often the real trouble, when in starting a motor it refuses to go, in which case it is better to shut off the fuel and turn the fly-wheel over to clear the cylinder of the first charge with the relief-cock open; it should always be open in starting to save the severe work of compression. The same difficulty may also occur in charging a self-starting motor of the larger size, which cannot be turned over to relieve the cylinder of the misfired charge, but by lifting the exhaust-valve and charging lightly with some pure air or fuel, as the judgment of the engineer may suggest, the start may be made. Herein lies the value of positive and full instruction that every builder of explosive motors should furnish with each motor sent out, as well as a practical lesson whenever possible to the person that is to operate the motor.

Do not once think because a motor slows down by the turning on of one or two more machines than it has been giving power to, that more fuel is all that is needed, for it may have been running with more or less fuel than was due to the greatest mean pressure. It may be noted that 1 part good illuminating gas to 6 parts air or 1 part of heavy oil-gas to 9 parts air, or 1 part gasoline-vapor to 8 parts air gives the quickest explosion, the highest explosive temperature, and the greatest mean pressure. Any departures from these proportions in the mixtures are weakening in their effects, and where the highest power and efficiency of the motor is required, any variation from the above-named proportions is not the most economical in practice. As between the hit-and-miss charges and the graduation of the charge in its best mixture, there has been and is a margin for discussion in which builders of explosive motors do not agree, and may not, until long experience, trials, and new methods of regulation may lead to the best practice.

CHAPTER XIX

EXPLOSIVE-ENGINE TESTING

FOR the reason that elaborate and complicated tests have been made and exploited in other works on the gas-engine, which may be referred to for the details of expert work, the author of this work has decided to reduce the practice of testing explosive motors to a commercial basis on which purchasers can comprehend their value as a business investment for power. The disposition of builders of explosive engines to follow the economics in construction in regard to least wall surface in contact with the heat of combustion, and of maintaining the wall surface at the highest practical temperature for economical running by the rapid circulation of warm water from a tank or cooling coil, leaves but little to accomplish, save the proper size and adjustment of the valves and igniters for the engines, in order that they may properly perform their functions. The indicator card, if made through a series of varying proportions of gas or gasoline and air mixtures, will show the condition of the adjustments for economic working. The difference between the indicated power for the gas used by the card and the power delivered to the dynamometer or brake shows the mechanical efficiency of the engine. The best working card of the engine should be a satisfactory test to a purchaser that the principles of construction are correct. A brake-trial certificate or observation should satisfy as to frictional economy, and the price and quantity of gas per horse-power hour should settle the comparative cost for running. The variation in the heating power of illuminating gas in the various parts of the United States is much less than its variation in price. Producer-gas is a specialty for local consumption, and its cost drops with its heating power.

Apart from the actual cost of gas in any locality and the quantity required per brake horse-power, durability of a motor is one of the principal items in the purchase of power.

In the use of gasoline, kerosene, and crude petroleum in explosive engines, their heating values are uniform for each kind, and as motors are generally adjusted for the use of one of the above hydrocarbons only, the difference of cost between these various fuels is the best indication as to the relative cost of power.

No instruments have yet been contrived for giving the temperatures of combustion, either initial or exhaust, in an internal-combustion motor; for at the proper working speed the changes of temperature are so rapid that no reliable observation can be made even with the electric thermostat, as has been tried in Europe. The computed temperatures are unreliable and at best only approximate; hence the indicator card becomes the only reliable source of information as to the action of combustion and expansion in the cylinder, as well as to the adjustment of the valves and their proper action.

The temperature of combustion as indicated by the fuel-constituents, and computed from their known heat values, gives at best but misleading results as indicating the real temperature of combustion in an explosive engine. There is no doubt that the computed temperatures could be obtained if the contaminating influence of the neutral elements that are mixed with the fuel of combustion, as well as the large proportion of the inert gases of previous explosions, could be excluded from the cylinder, when the radiation and absorption of heat by the cylinder would be the only retarding influences in the development of heat due to the union of the pure elements of combustion.

For obtaining the indicated horse-power of a gas, gasoline, or oil-engine, the mean effective pressure as shown by the card may be obtained by dividing the length of the card into ten or any convenient number of parts vertically, as shown in Fig. 244, for a four-cycle compression-engine. For each section measure the average between the curve of compression and the curve of expansion with a scale corresponding with the number of the indicator-spring. Add the measured distances and divide by the number of spaces for the mean pressure. With the mean pressure multiply the area of the cylinder for the gross pressure. If there have been no misfires, then one-half the number of revolutions multiplied by the stroke and by the gross pressure, and the product divided by 33,000, will give the

indicated horse-power. If there is any discrepancy along the atmospheric line by obstruction in the exhaust or suction-stroke, the average must be deducted from the mean pressure.

The exhaust-valve, if too small, or with insufficient lift, or a too small or too long exhaust-pipe, will produce back-pressure on the return line, which should be deducted from the mean pressure. A small inlet-valve or too small lift, or any obstruction to a free entry of the charge, produces a back-pressure on the outward or suction-stroke and a depression along the atmospheric line, which must also be deducted from the mean pressure.

It is assumed that the taking of an indicator card must be done when the engine is running steadily and at full load. During the

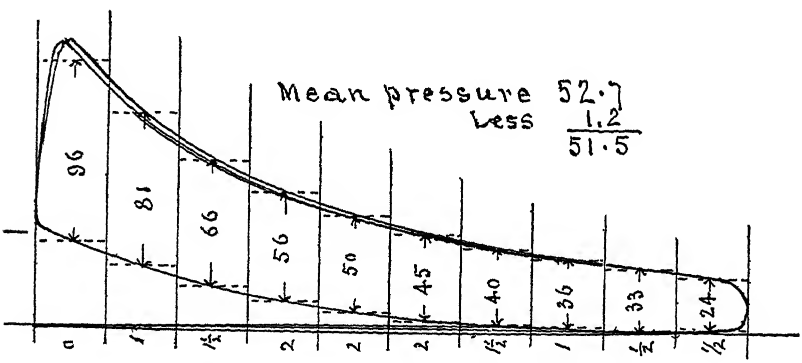


FIG. 244.—Four-cycle gas-engine card.

moment that the pencil is on the card there should be no misfires recorded, in order that the card may represent the true indicated horse-power of the engine. The record of the speed of the engine should be taken at the same time as the card, but the measurement of the quantity of gas used cannot be accurately observed on the dial of an ordinary gas-meter during the few moments' interval of the card record and speed count. For the gas record, the engines should be run at least five minutes at the same speed and load and an exact count of the explosions made. The misfires or rather mischarges in an engine running with a constant load are of no importance in the computation for power because they are properly caused by overspeed, and the overspeed and underspeed should make a fair balance for the average of the run as indicated by the speed-counter.

The number of cubic feet of gas indicated by the meter for a few minutes' run, multiplied by its hour exponent and divided by the indicated power by the card or the actual horse-power by the brake, will give the required commercial rating of the engine as to its economic power. The difference as between the cost of gas for the igniter and the cost of electric ignition is too small to be worthy of consideration.

In testing with gasoline or oil the detail of operation is the same as for gas, with the only difference of an exact measure of the fluid actually consumed in an hour's run of the engine under a full load. The loading of an engine for the purpose of testing to its full power is not always an easy matter; although, when driving a large amount of shafting and steady-running machines, a brake may be conveniently applied to increase the work of the engine. In trials with a brake alone, a continual run involves some difficulties on account of the intense friction and heat produced, which makes the brake-power vary considerably and cause a like variation in the ignitions.

Probably the most satisfactory method of testing the power of a motor is by its application to generate an electric current, which, if properly arranged in detail, allows the test trial to be continued for a length of time and makes the test a perfectly reliable one. For this purpose the motor may be belted to a generating dynamo of the same or a little higher rating than that of the motor. A short wiring-system with a volt and ampere-meter and a sufficient number of 16-candle-power lamps in circuit, of a standard voltage and known amperage, will indicate the power generated in kilowatts, to which should be added the loss of efficiency in the dynamo.

From this data the actual horse-power of the motor may be computed, which with the fuel measurement and the speed of the motor during test trial is all that is needed for a commercial rating.

In testing motors with ordinary illuminating gas under street pressure as used for lighting purposes, the ordinary meter measurement will be found correct, but with natural or other gas supplied at high pressures, the pressure should be reduced by a pressure-regulator, or by drawing the gas from a properly weighted gas-holder. A one-inch water-pressure in an inverted glass siphon gives the proper pressure for meter measurement. The details for the

finer tests of explosive motors have but little commercial value and require much expert experience in the computations in such tests; so that for ordinary purposes in testing for best effect the cylinder-cooling water should be run long enough and with the engine running at full load to establish an overflow temperature of 175° Fah., which has been found to give a good working efficiency in the cylinder temperature. This may be readily obtained by regulating the quantity of flowing water. Then the actual measurement of the gas or other fuel and its cost as compared with the brake horse-power may be said to give a fairly just measure of its fuel-economy. The test of endurance is a strictly mechanical one due to design and quality of construction, which may be obtained, first, by inspection or detailed examination of the motor, and further from guarantee of the builder.

BACK-FIRING IN EXPLOSIVE MOTORS

The so-called back-firing may be located in the exhaust-pipe or passages and is usually caused by a misfired charge being fired by the exhaust of the next impulse-charge. It may be recognized by its peculiar sound and seen at the exhaust-pipe terminal. The cause of misfiring is a frequent effect of the uncertainty of hot-tube ignition in which there is variation in the temperature of the tube at the proper point, when the greatest compression occurs. This peculiar condition has brought out the use of timing valves in large engines.

The regulation of engine speed by varying the gas charge makes a variation in temperature at the ignition of the charges and so makes misfires a persistent tendency. Short-circuiting of the electric current in the break and jump-spark ignition systems is often a puzzling trouble to locate when the motor gets to kicking.

There is another form of back-firing which is more perplexing still. It occurs in the inlet passage between the point of air admission or mixing-valve and the actual inlet to the cylinder. The first and most readily perceived is a leaky inlet-valve, transmitting the combustion within the cylinder to the mixture without. The other is based on the theory that the combustion of a lean mixture or a rich mixture is a prolonged one, and that a lingering flame holding over during exhaust-stroke and until the next opening of the

inlet-valve fires the supply in the mixture chamber. Invariably it has been the case of the lean mixture, notwithstanding the foredrawn conclusion that it should be with the other, that the lean mixture, with its excess of oxygen, would be snapped up and quickly consumed; that the rich mixture, seeking out the last atom of oxygen, would linger in the inlet chamber, unexploded.

Irregularity of explosion, often a source of apprehension as to back-firing, is due to extreme governing action at full or partial load, which may need no further investigation than to find and correct, if the governor is not acting freely. A sticking action of the governor, often unnoticed, may lead to a suspicion of other troubles. The effect of irregular governing is shown in explosions of various strength in succession or at various intervals.

This is one of the points requiring careful management in starting suction gas-motors with gasoline. The change from the feed-adjustment of a high-compression suction gas-motor for starting with gasoline should be so arranged as to allow of the least injection of gasoline that will produce an explosive charge, and thus avoid possible danger that may arise from a rich charge in a motor designed for weak charges.

FIRE UNDERWRITERS' REGULATIONS REGARDING THE INSTALLATION AND USE OF GASOLINE-ENGINES

Rules and requirements of the National Board of Fire Underwriters for the installation and running of gasoline-engines.

As these rules are standard for practically all of the United States, they should be of interest to both the manufacturer and the user of gasoline-engines.

The rules for installation are as follows:

1. *Location of Engines—*

a. Should, wherever possible, be located on the ground-floor.

b. In workshops or rooms where dust and inflammable flyings prevail, the engine to be enclosed in a fire-proof compartment well ventilated to the outer air at floor and ceiling.

c. If located on a wooden floor the engine to be set on a metal plate turned up at the edges.

2. *Supply-tank*—

a. Shall be located outside the building, underground, where possible, at least thirty feet removed from all buildings, and below the level of the lowest pipe in the building used in connection with the apparatus.

b. If impracticable to bury the supply-tank, the same may be installed in a non-combustible building or vault properly ventilated, preferably from the bottom, always remembering that it must be below the level of the lowest pipe in the building used in connection with the apparatus.

c. Auxiliary inside tanks, if used, shall not exceed one quart in capacity, and shall not be placed on, in, or under the engine, and shall be so arranged that when the supply-valve is closed a drain-valve into the return-pipe will be automatically opened. (See also paragraph 8, Note.)

3. *Piping*—

a. None but tested pipe to be used.

b. Connections to outside tank shall not be located near nor placed in the same trench with other piping.

c. Openings for pipes through outside walls shall be securely cemented and made water and oil-tight.

d. Piping to be run as direct as possible.

e. Piping for gasoline-feed and overflow from auxiliary inside tank and feed-cup shall be installed with a good pitch so the gasoline will drain back to the supply-tank.

f. Fill and vent-pipes leading to the surface of the ground shall be boxed or jacketed to prevent freezing of earth about them and loosening or breakage of connections.

4. *Muffler or Exhaust-pot*—

a. Shall be placed on a firm foundation and be kept at least one foot from woodwork or combustible materials.

5. *Exhaust-pipe*—

a. Exhaust-pipe, whether direct from engine or from mufflers, shall extend to the outside of the building, and be kept at least six inches from any woodwork or combustible material, and if run through floors or partitions shall be provided with ventilated thimbles.

b. Shall in no case discharge into a chimney.

6. *Care and Attendance*—

Due consideration shall be given the cleaning of the cylinder, valves, and exhaust-pipe as often as the quality of the fuel may necessitate.

The rules for construction are as follows:

These rules are not to be considered as specifications for the shop construction of an engine, inasmuch as questions of design, efficiency, and operation are largely omitted. They cover only the outlines of construction of parts of special interest to the underwriters, and it should be noted that all engines conforming to the same are not of equal merit.

7. *Outside Supply-tank*—

a. Must be constructed of iron or steel plate, securely riveted together or pressed into form. Tanks should be galvanized, or painted on the outside with rust-proof paint.

b. Must be provided with a fill-pipe and a vent-pipe.

c. The fill and vent-pipes to terminate in an iron box, cover of which should be flush with the ground, and locked with a padlock.

These pipes should be provided with screen near the top and the box to be properly ventilated.

8. *Inside Auxiliary Tank*—

Note. Auxiliary inside tanks with gravity feed are not advised as their use requires extra piping and fittings and an additional receptacle containing gasoline is introduced within the premises.

The gasoline feed-cup provided for below is sufficient for all ordinary purposes.

a. Must not exceed one quart in capacity and must be constructed in an improved manner of brass or copper of at least No. 20 B. and S. gauge or else made in a casting.

b. Must have no valves or plugs opening into the room with the exception of an air-vent.

c. Must be provided with an overflow connection draining to the outside supply-tank.

9. *Gasoline Feed-cup*—

a. Must be of cast metal rigidly secured to the engine-frame or mixing chamber, and must not exceed in capacity one-half pint.

b. Must be provided with an approved controlling-valve or regulator.

c. Must be arranged to prevent spattering, dripping, or exposure of gasoline during operation or with the engine at rest.

d. Must be provided with an overflow connection draining to the outside supply-tank.

10. *Gasoline Feed-pump*—

a. Should be of the simple single-plunger type with check-valve as close to the pump as convenient.

b. No packing should be used on plunger of pump.

11. *Igniter or Exploder*—

a. Electric ignition must be used.

12. *Muffler or Exhaust-pot*—

a. Must be made equal in strength to the cylinder or other parts subject to effects of the explosion, and should be made in cylindrical or spherical form with as few joints as possible.

b. Must be provided with a draw-off or drain-valve placed near the bottom and below the exhaust-pipe connection.

13. *Valves*—

a. Shut-off valves must close against the gasoline supply, must be made of brass and have a stuffing-cap of liberal size arranged to force the packing against the valve-stem.

b. No packing likely to be affected by gasoline to be used.

c. Regulating valves, if not designed to close against the gasoline supply, or if used as a shut-off valve, must be provided with a special stuffing-cap having a follower-gland designed to hold and compress the packing.

Note: Engine-valves of the poppet type should preferably be so placed that gravity will act with spring to keep the valve closed.

14. *Pipings and Fittings*—

a. Tank and drain-piping must be of brass or iron, not smaller than $\frac{3}{8}$-inch size. Drain-pipe to be at least one size larger than supply-pipe.

b. Connections by right and left couplings are advised in place of unions.

If unions are used they must be of brass, with a ground conical joint, obviating the use of packing or gaskets.

c. A filter must be provided in the gasoline supply-pipe located near the engine and accessible for purpose of cleaning.

Note: A substantial flange-fitting containing fine brass gauze is recommended for use as a filter.

15. *Engine Base—*

a. Must not be used as a storage space for gasoline or any other material.

b. It is recommended that the base be constructed with a groove or channel to prevent lubricating-oil from soaking into floors.

16. *Lubricating Oil-drips and Pans—*

a. Must be provided where necessary to prevent the spilling of oil.

b. Cranks and other rapidly revolving or reciprocating parts must be shielded to prevent throwing of oil.

17. *Name-plate—*

a. Must be provided with a plate giving the name of the manufacturer, the trade-name of the engine, and its rated horse-power.

The Southeastern Tariff Association, operating in Alabama, Florida, Georgia, North and South Carolina, Virginia, and some other Southern States, uses the following gasoline-permit:

Specifications to which all gasoline-engines must conform in order to be approved for their installation:

1. Engines to be ignited by electric spark; tube-igniters not allowed.

2. Storage-tanks for gasoline shall be located under ground, outside of the engine-room, and top of tank shall be below the level of the base of engine and not less than ten feet away from any building. Gasoline must be drawn from the general supply-tank, either to the engine, or the auxiliary or secondary reservoir or receptacle into which the pump discharges, and out of which the gasoline is fed into the engine. The overflow of said auxiliary or secondary reservoir or receptacle must lead back to the main storage-tank and be of four times the capacity of the pump.

3. Tanks to be cylindrical in shape and constructed as follows: viz., less than 200-gallon capacity to be of not less than $\frac{1}{8}$-inch steel throughout. Tanks of 200 to 300-gallon capacity to be of not less than $\frac{3}{16}$-inch steel throughout; heads to be stayed with iron; seams of all tanks to be securely riveted and caulked. Tanks to be coated with tar before being placed in the ground. No tank of larger than 300 gallons allowed.

4. Pipes leading from storage-tank to engine must be put together at every joint, metal to metal, with pipe-screw connections. Supply and overflow-pipes to incline toward tank in order that surplus gasoline may drain back to tank from building when engine is not in operation; hand-valves to be placed in each supply and overflow-pipe outside of building, said valves to be closed when filling tank and when engine is shut down for the night. A vent provided with screw-cap must be attached to tank, said pipe to be open during filling. Storage-tank must be always filled by daylight, and all attachments between supply-wagon, tank-car, or barrels shall be tight-fitting screw-connections.

5. Any form of carbureter or vaporizer (that is, engines with a carbureter or vaporizer so constructed that by the passing of air over or through the gasoline the explosive mixture is formed within the carbureter or outside of the engine cylinder) is prohibited. This rule will apply except where vaporizer or carbureter has been specifically approved by this Association.

KEROSENE-OIL ENGINES

In New York City gasoline-engines are prohibited. The following are the requirements of the New York Board of Fire Underwriters for the installation and use of kerosene-oil engines:

Location of Engine—

Engine shall not be located where the normal temperature is above 95° F., or within ten feet of any fire.

If enclosed in room, same must be well ventilated, and if room has a wood floor, the entire floor must be covered with metal and kept free from the drippings of oil.

If engine is not enclosed, and if set on a wood floor, then the floor under and three feet outside of it must be covered with metal.

Feed-tank—

If located inside the building, shall not exceed five gallons in capacity, and must be made of galvanized iron or copper, not less than No. 22 B. and S. gauge, and must be double seamed and soldered, and must be set in a drip-pan on the floor at the base of the engine.

Tanks of more than five-gallon capacity must be made of heavy

iron or steel, be riveted, and be located, preferably, underground outside of the building. If there is no space available outside the building for a tank, it may, by written permission from this Board, be located in an approved vault attached to the building, or in a non-combustible and well-ventilated compartment inside the building, but no such tank shall exceed five barrels capacity.

Tanks, irrespective of the method of feed, must not be located above the floor on which the engine is set.

The base of an engine must not be used in lieu of a tank as a receptacle for feed-oil. A tank, if satisfactorily insulated from the heat of the engine, and approved by the Board, may be placed inside of the base.

In starting an engine, gas only, properly arranged, must be used to heat the combustion-chamber.

A high-grade kerosene oil must be used, the flash test of which shall be not lower than 100° F.

Oily waste and rags must be kept in an approved self-closing metal can, with legs to raise it six inches above the floor.

The supply of oil, unless in an approved tank outside the building, or in a non-combustible compartment, as above provided for, shall not exceed one barrel, which may be stored on the premises, provided same is kept in an unexposed location ten feet distant from any fire, artificial light, and inflammable material, and oil drawn by daylight only.

A drip-pan must be placed under the barrel.

Empty kerosene barrels must not be kept on the premises.

CHAPTER XX

GAS AND GASOLINE-MOTORS—THE AMATEUR'S MOTOR

We illustrate in the following pages a gas or gasoline-motor most suitable for amateur workmen who wish to build for themselves an experimental power-motor. The motor is of the four-cycle type of about 1½ horse-power. The castings and all parts, even the necessary screws, with the blue prints for working finish, or the most difficult parts are furnished machined with the blue

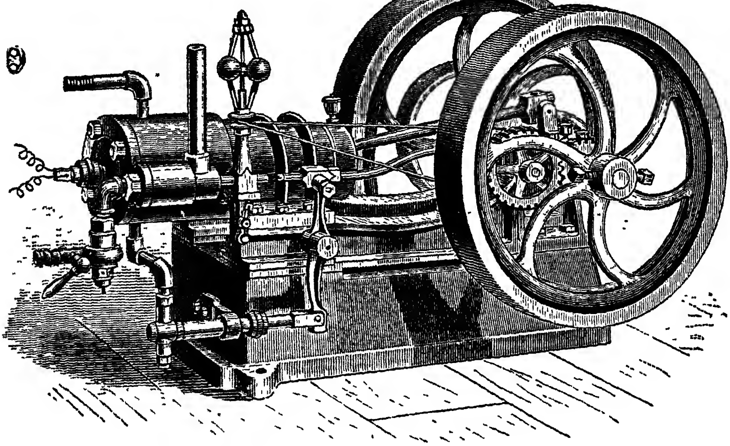


Fig. 245.—The Weed gas or gasoline-motor.

prints and instructions by The Sipp Electric and Machine Company, Paterson, N. J. The blue prints contain all details of the parts and may be purchased separate, if desired, for $2.50 for the set. A complete set of the castings, parts, and screws, with the blue prints for $15; thus saving the most difficult part of the work for amateurs, the pattern-making.

It will be seen that the push-rod from the crank on the secondary shaft operates the exhaust-valve and also the circulating-pump for forcing water from a tank near by; but when located where there is a flow of water, or if the use of an elevated cooling tank can be utilized, the pump may be left off. The action of the governor is

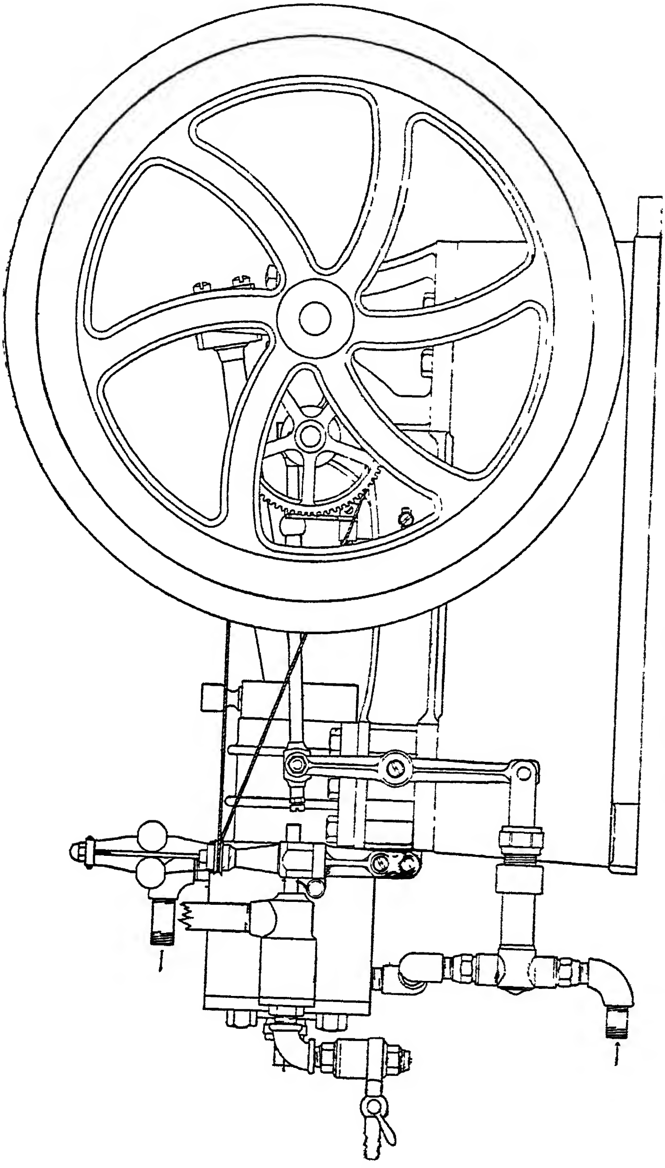


FIG. 246.—The Weed gas or gasoline-motor.

very simple; the end of the spindle drops into a notch in the valve-spindle when the speed is excessive, holding the valve open for miss-charge until the normal speed is regained. Where illuminating

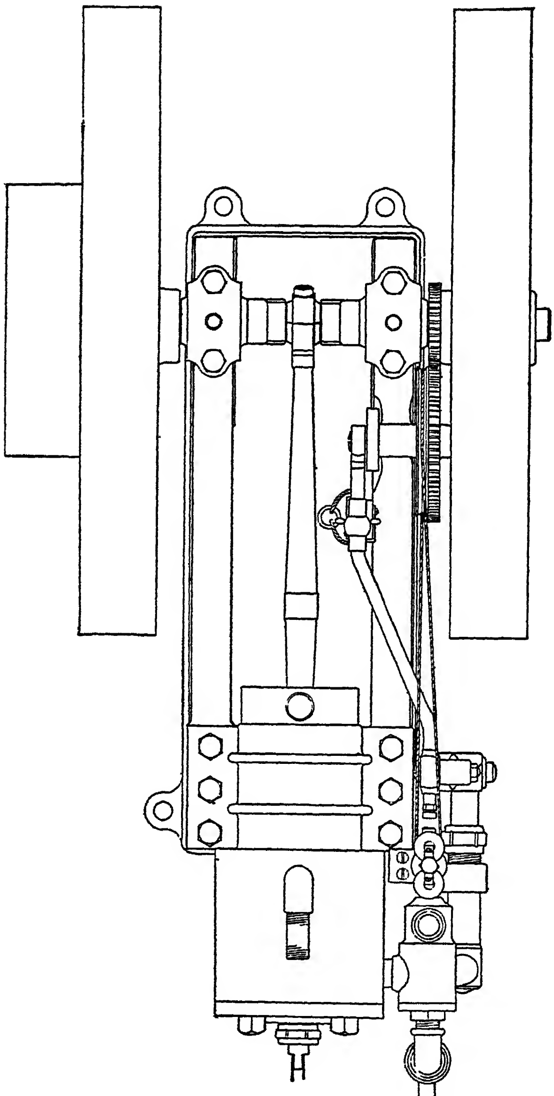


FIG. 247.—Plan of Weed motor.

gas is not available, an independent carbureter is supplied to produce an air and vapor gas from gasoline, using a rubber tube to connect the carbureter directly to the gas-cock nozzle.

MOTORS OF THE GEMMER ENGINE AND MANUFACTURING COMPANY, MARION, IND.

The gas and gasoline-engines of this company are of the four-cycle type made on the standard principles of design. The valve and ignition-gear is novel in design; the governor, igniter-trip, and gasoline-pump are all operated from the reducing-gear pin by a connecting-rod to a slide to which the inertia governor and gasoline-pump are attached, making a hit-and-miss regulation.

The governor is very simple, consisting only of a weight, a hardened steel finger, and a small spring. The speed is changed

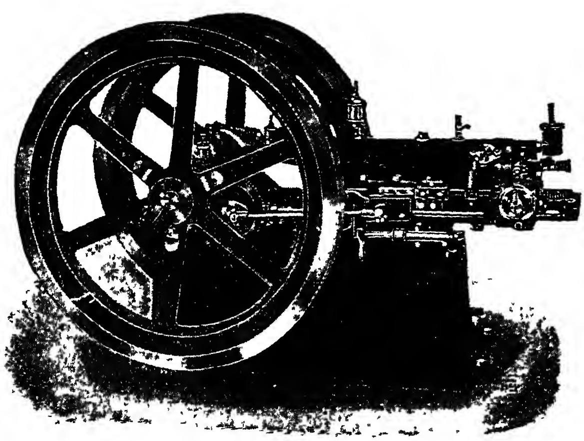


FIG. 248.—The Gemmer gas and gasoline-engine.

by adjusting the spring by means of a knurled thumb-screw. *This is easily done while the engine is running.*

The carriage rides on a steel slide, which gives it a very durable bearing. An adjustable-gib provides for wear.

In operation, when the engine is below normal speed, the governor-finger engages with the sliding bar, as shown in cut, driving it forward and opening the fuel-valve (the round stem shown at end of bar), permitting a charge to be drawn into the cylinder. As the carriage returns it engages with a pin on the bar and draws it back, and the igniter is snapped, igniting the compressed charge, and giving an impulse that brings the engine up to the proper

speed. When above normal speed the governor-weight drags behind and causes the finger to miss the bar, letting it remain stationary. This leaves the fuel-valve closed, and only pure air is drawn into the cylinder, until the speed again falls below normal and the finger engages the bar as before. As shown, the igniter-trip is mounted on the sliding bar and moves only when it does, *hence the igniter is snapped only when a fuel charge is admitted, thus more than doubling the life of the igniter-points and the batteries.*

The carriage operates the lunger of the pump, that draws

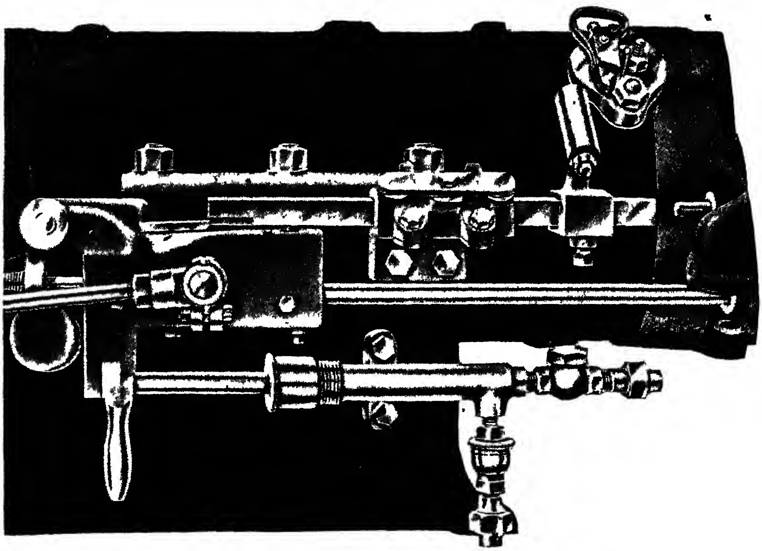


FIG. 249.—Valve and pump gear; Gemmer engine.

the gasoline supply from a tank placed under the ground, outside the building, and forces it into a small reservoir above the vaporizer. The plunger ends in a handle, that has a projection which fits in between two lugs on the carriage, and by which it is drawn back and forth. This plunger may be operated by hand, independently of the carriage, by simply raising the handle to a horizontal position.

The operation and general principles of construction of the vertical engine are the same as the horizontal and, in general, the same description of details applies to this type.

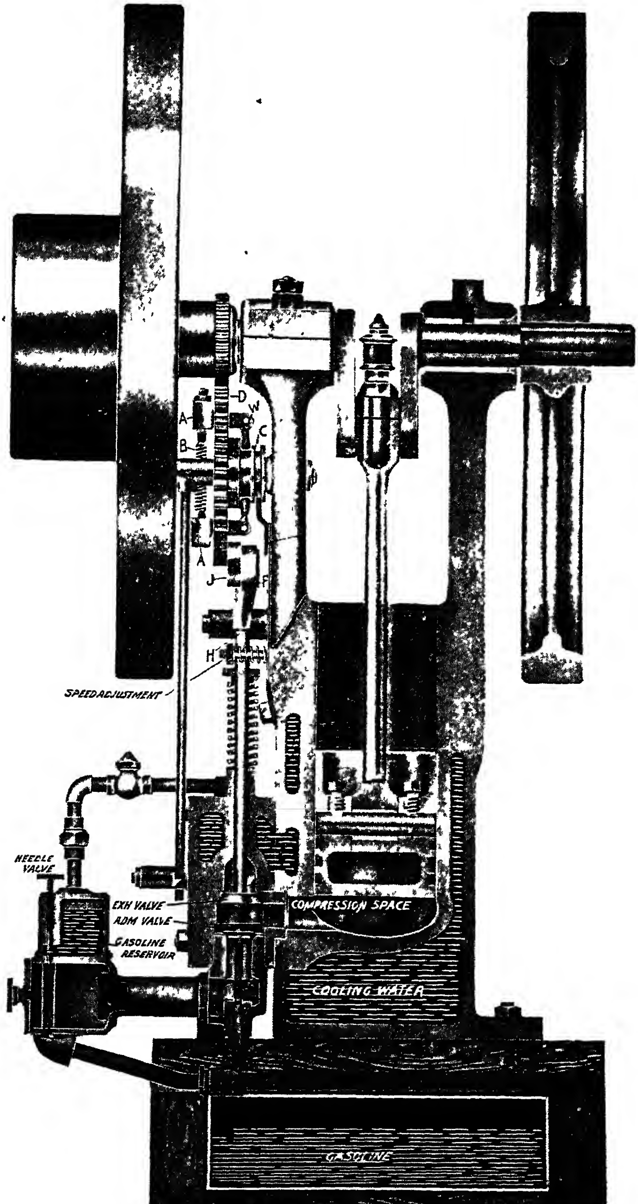


FIG. 250 —Gemmer vertical engine.

The cylinder is placed downward, with the crank-shaft up, as it can be lubricated much better and all parts, especially the piston and connecting-rod, are much easier to get at than if the cylinder were the other way up.

The governor is attached to the reducing-gear. AA are the weights. When the speed is above normal, these weights fly out, overcoming the tension in the spring B and sliding hardened steel collar C toward the gear-wheel D, when the steel piece E on the lever F engages with the steel catch G and holds open the exhaust-valve. The exhaust-valve is opened by a cam W on gear D, pressing down on roller J mounted on a hardened steel pin in lever F, which presses down the stem H, opening the valve. When the speed returns to normal and the cam again presses down stem H the tension of the spring B brings the weights AA together, moving the collar C so that the E returning misses the catch G, permitting the valve to close, when the engine takes up its regular cycle. This governor is very sensitive and holds the speed constant, making the engine suitable for operating a cream-separator or any machine requiring a steady speed.

The pump draws the gasoline from the supply tank, which may be placed outside of the building, thus complying with the insurance regulations. The engine is shipped with this tank in the wooden sub-base, as shown in the section. The pump may be worked by hand at will, which is a great convenience, as the gasoline-vaporizer reservoir must be filled before starting.

In the vaporizer the gasoline is fed through a sight-feed needle-valve and drops onto a brass wire screen, where it is caught by the incoming air and sprayed through other screens of graduated meshes, atomizing it perfectly. This vapor passes through the fuel-valve, opened at the proper time by the governor, and is mixed with the necessary amount of air for perfect combustion and enters the cylinder through the inlet-valve. Any possible mixture of vapor and air desired is obtained by simply turning the brass knob, which controls the passages to both the gas and air chambers of the vaporizer.

The gas-engines of the Westinghouse Machine Company, East Pittsburgh, Pa., are built in the vertical and horizontal form of the four-cycle type peculiar to their unique design, and also a new

type of double-acting model in single and cross-tandem units of great power.

In Fig. 251 we illustrate a section of their standard vertical model which is built in units of one, two, and three-cylinder combinations, in sizes from 10 to 300-brake horse-power.

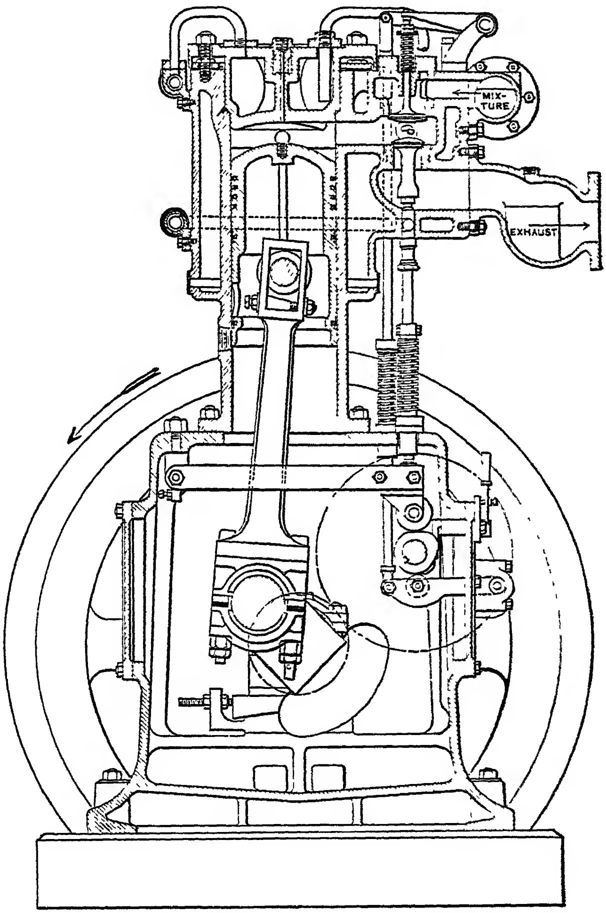


FIG. 251.—Westinghouse standard vertical gas-engine.

Among the claims for special good service in the Westinghouse motors are pistons of unusual length, nearly twice their diameter, providing ample bearing surface. A cylinder centre-line offset from crank-centre on the impulse side, for reducing the angularity of

the connecting-rod on the power stroke. All valve and igniter movements controlled by a single cam-shaft.

The governing is by a centrifugal fly-ball type that controls the speed by varying the quantity of fuel mixture.

In Fig. 252 is shown the double-break spark-igniter, which is also a novelty, and which may be made to give simultaneous or successive sparks as found best for perfect ignition.

Duplex ignition, by its constancy of action, is a most desirable feature of uniformity in the running of large units for electric lighting and power.

In Fig. 253 is illustrated the three-throw shaft of this com-

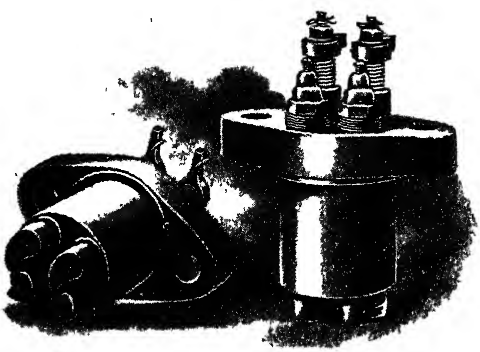


FIG. 252.—Westinghouse ignition-plug

pany with cranks at 120°, counterbalanced and showing the method of bolting on the counterbalance.

In Fig. 254 we illustrate the new double-acting gas-engine of the Westinghouse Company.

In construction the engine embodies many established features of modern steam-engine practice. From crank to cylinders the construction is that of a horizontal steam-engine suitably strengthened in proportion to the increased maximum pressure due to the explosion of the charge. The design of cylinders, pistons, and valves, of course, departs materially from steam-engine practice. The cylinders are double-walled, with the outer walls split peripherally to permit independent expansion and contraction without placing the cylinder-casting under stress.

The many difficulties arising in providing a suitable packing-gland for the cylinder-heads have been overcome by means of a simple metallic packing similar in some respects to that used on high-pressure steam-engines.

Both valves are of the single-beat poppet type and seat vertically along the same axis, the admission-valve opening downward and the exhaust upward. The admission-valve is mounted in a separate bonnet which, together with the valve, may be readily removed without dismantling any parts of the engine other than the tappet-lever through which the cam motion is imparted to the valve. Both admission and exhaust valves are of steel and are held to their seats by spiral springs. The exhaust-valve is water cooled.

FIG 253 —Three-cra .k counterbalanced-shaft

It is bored hollow throughout its length, and this canal conveys cooling water to the head of the valve: the water returns in the opposite direction through an inner concentric tube, finally emerging at the lower ènd. By spraying a small part of the jacket-water into the exhaust-pipes, the temperature of the pipe may be kept at a comfortable point through the absorption of the latent heat of evaporation of the water used.

Both pistons and the piston-rod are water cooled, as well as other parts subjected to internal heat. Means for introducing the cooling water is secured by a telescopic pipe connection bolted to the inside of the cross-head guide. The inner tube of this telescopic joint is attached to the cross-head at such a point as to convey the cooling water to the end of the piston-rod bore, whence

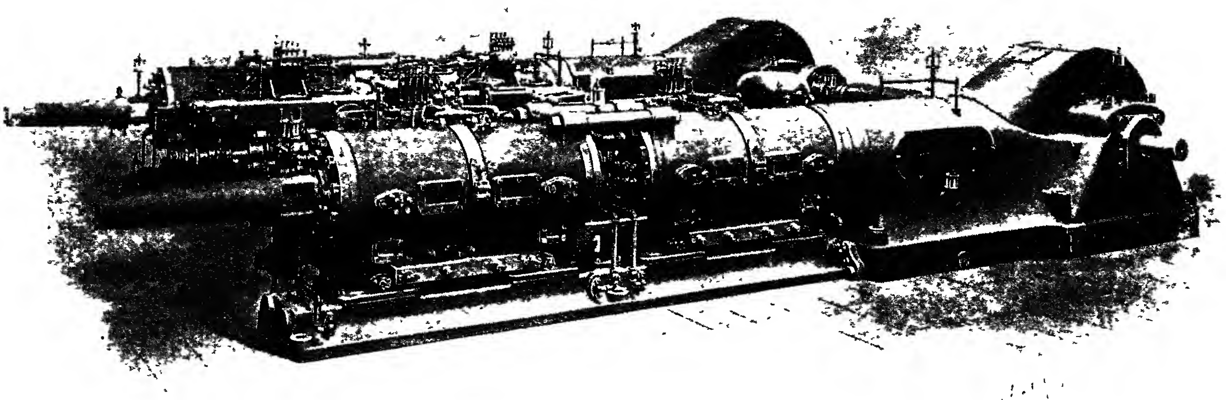


Fig. 254.—The Westinghouse four-cylinder, double-acting gas-engine.

our-cycle type, cranks 90° apart, giving four impulses per revolution, in units from 400 to 2,000 horse-power The pistons, piston-rods, and exhaust-valves are all water cooled. One-lay shaft, parallel with and running between the cylinders, operates through independent cams the inlet and exhaust valves and the igniters, so that the action of the valves and igniters may be timed in order to secure the best results

it proceeds in succession through the two pistons, emerging through a bronze tail-rod extending through the rear cylinder-head. Each piston is a one-piece casting, cored hollow to accommodate the circulating water, and packed by cast-iron packing-rings set out with flat steel springs. In order to convey the water in and out of the piston, deflecting plugs are inserted at the proper points in the rod-bore. A cast-iron jacket surrounds the tail-rod and receives the water emerging from it, whence it is drained away.

The one-lay shaft paralleling the cylinders operates, through cams, all of the valve movements of the engine. Independent cams are provided for inlet-valves, exhaust-valves, and igniters, so that the action of each valve may be timed in order to secure the best results. The main cams are all of cast iron with working surfaces chilled and ground.

The engine is started by compressed air, and for this purpose a special disengaging gear is provided which isolates the rear cylinder, and on admitting the compressed air allows the cylinder to operate as an air-motor until the regular combustion cycle is taken up in the forward cylinder; the rear cylinder may then be thrown into normal action.

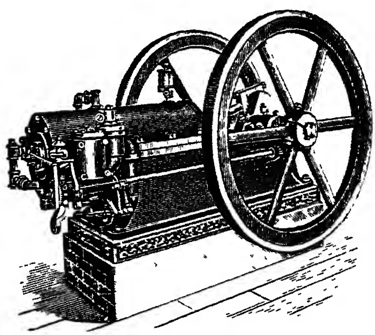


FIG. 255.—The Lambert gas and gasoline-engine.

The engines built by the Lambert Gas and Gasoline Engine Company, Anderson, Ind., are all of the horizontal four-cycle type. They are scheduled in fifteen sizes, from 1 to 40 B. H. P. The valves are all of the poppet type and are operated by a secondary shaft and worm reducing-gear. The exhaust-valve is opened by a lever across and under the end of the cylinder, the lever having a roller riding against a cam on the secondary shaft. The exhaust-chamber has a water circulation through a jacket, and the cylinder-head is also jacketed and connected, so that there can be no leak into the cylinder from the water circulation.

In Fig. 255 is shown the left side with the valve gear and loca-

tion of the governor, which is driven by a bevel gear on the secondary shaft.

In Fig. 256 is shown the detailed end view of the engine; the bell-crank lever that operated the gas inlet-valve from a cam on the secondary shaft, as also the sparking-cam *o* at the end of the shaft.

The spark-breaker and electrode are fixed on a small-eared flange bolted to the cylinder-head, through which a rock-shaft and

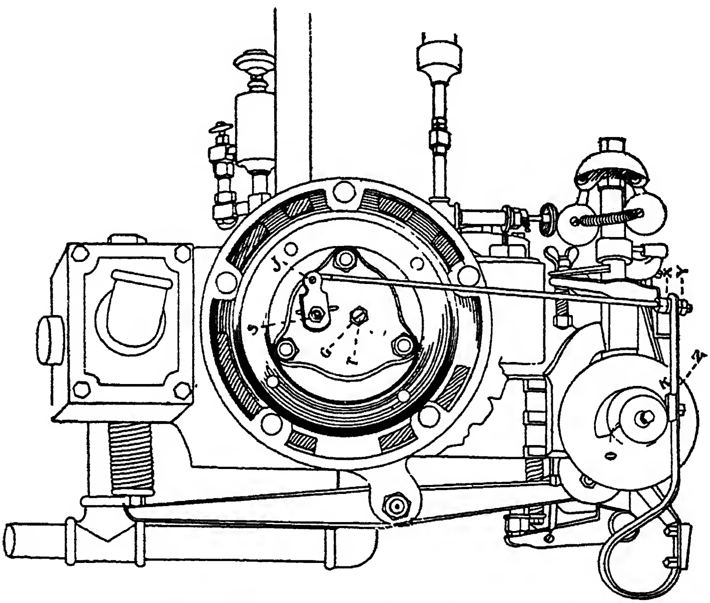


FIG. 256.—The Lambert valve and ignition-gear.

insulated electrode pass. One arm of the rock-shaft presses the electrode on the inside, while the outside arm is attached to a connecting-rod, operated by the spring lever *z* and cam-block *k*, which is adjustable. The amount of pressure of the inside arm is adjusted by the nuts *x* and *y* on the connecting-rod.

In Fig. 257 is shown the electric battery, sparking-coil, and wiring, in which H and G are the binding-posts on the valve-chamber and insulated electrode. A relief-cock is furnished for starting these engines.

In Fig. 258 is shown the gas-regulator used with the Lambert

engines—a most useful adjunct where the gas-pressure is not uniform. A priming-cup for starting the gasoline-engines and a gasoline-pump operated by the cam-shaft are not shown in the cuts.

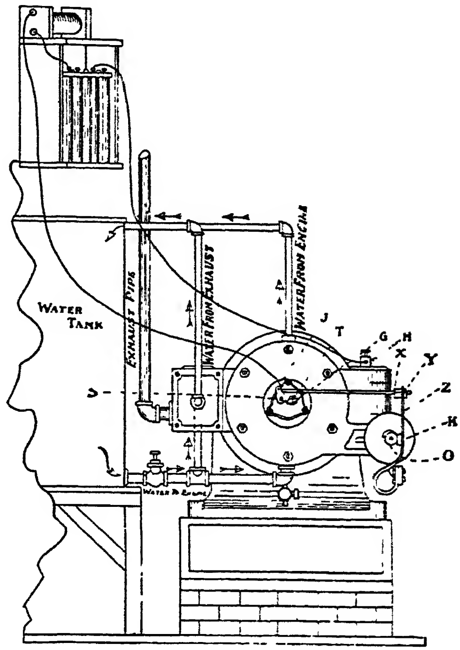


Fig. 257.—The electric connection.

The "Leaflet" of directions issued by the Lambert Company is an excellent guide to the operator of a gas or gasoline-engine, and gives special directions for observing the internal action of the engine by the sounds to the ear.

The stationary and marine engines of the Union Gas Engine Company, San Francisco, Cal., are all of the four-cycle type and adapted to the use of gas, gasoline, distillate kerosene or crude oil, as required for their special work.

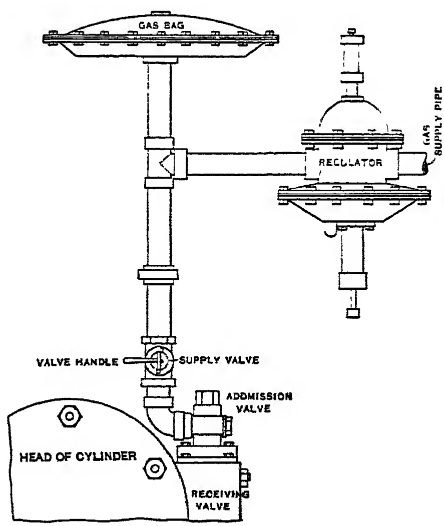


Fig. 258.—Gas-regulator and gas-bag.

The fuel, gasoline or oil, is drawn from a float feed-chamber meeting the hot air from the exhaust-heater, by which it is made a perfect mixture before passing the inlet-valve. Fig. 260 illustrates their latest type

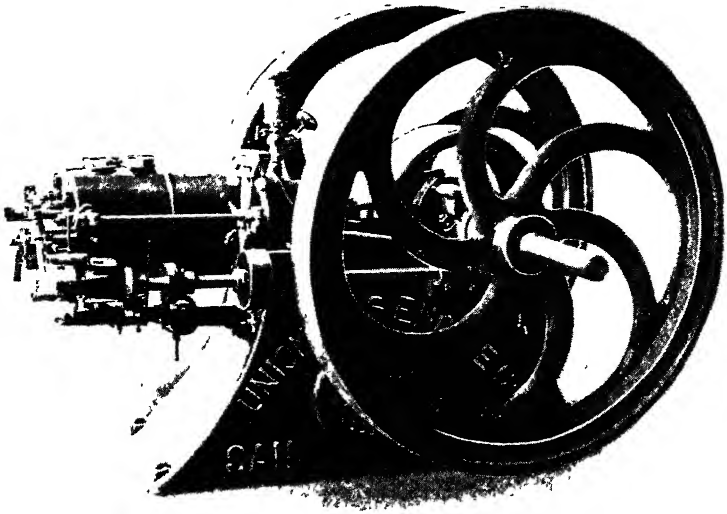


Fig. 259.—Horizontal engine, for gas, gasoline, or kerosene oil.

of vaporizer, the upper section of which contains a throttle-valve controlled by the governor.

Their marine engines are built in one, two, three, and four-cylinder units with all the latest improvement in the running gear and regulating appliances. Their vertical motors are fitted in portable form for all kinds of agricultural and mining work. Their tunnel locomotive is a model of completeness.

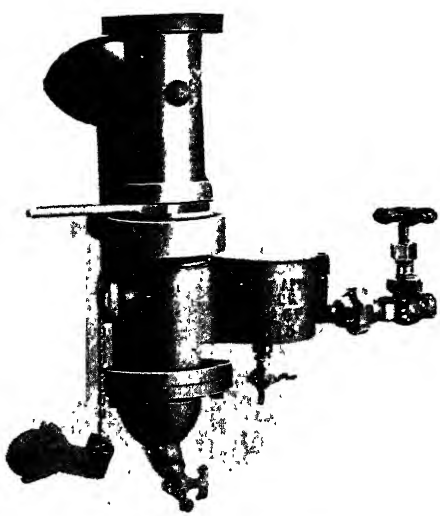


Fig. 260.—Union vaporizer.

The engines of the White-Blakeslee Manufacturing Company, Birmingham, Ala., are of the horizontal and vertical model and four-

cycle compression type. The horizontal engines are built in single-cylinder units of eight to thirty-six B. H. P., and the vertical engines in units of one to six B. H. P. Direct-tandem compressed-air cylinders and pumping outfits are in their line. In these engines the gasoline-pump throws a regulated charge of fuel into a vaporizing chamber beneath the cylinder, where it meets the in-

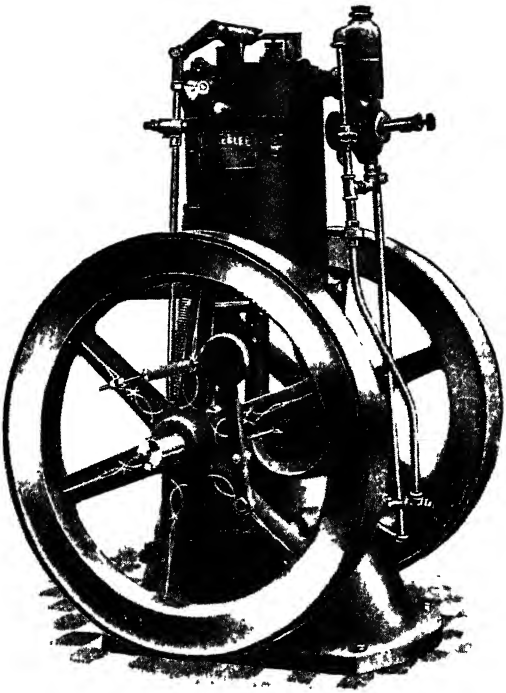


FIG. 261.—Blakeslee vertical engine.

coming air by the suction of the piston producing the proper proportion of air and gasoline mixture as regulated by the gasoline and air valve. The governing is by varying the charge by the action of a throttle-valve operated directly by the governor at the upper end of the vaporizer—above which is placed the inlet-valve. The exhaust-valve is in a chamber at the opposite side of the cylinder and operated by a cross lever from a cam on the side-shaft. Ignition is by contact break spark.

The vertical engine receives its charge from a constant-level reservoir regulated in the same manner as the horizontal style. The inlet and exhaust valve and the igniter are all located in the head of the cylinder. Both valves and the igniter are operated by a push-rod from the reducing gear, and regulation is by a governor on the fly-wheel.

ENGINES OF THE HARTIG STANDARD GAS-ENGINE COMPANY, NEWARK, N. J.

The motors of this company, both horizontal and vertical, are of the four-cycle type and are governed by a pendulum or inertia-governor operating on the hit-and-miss principle on the exhaust-

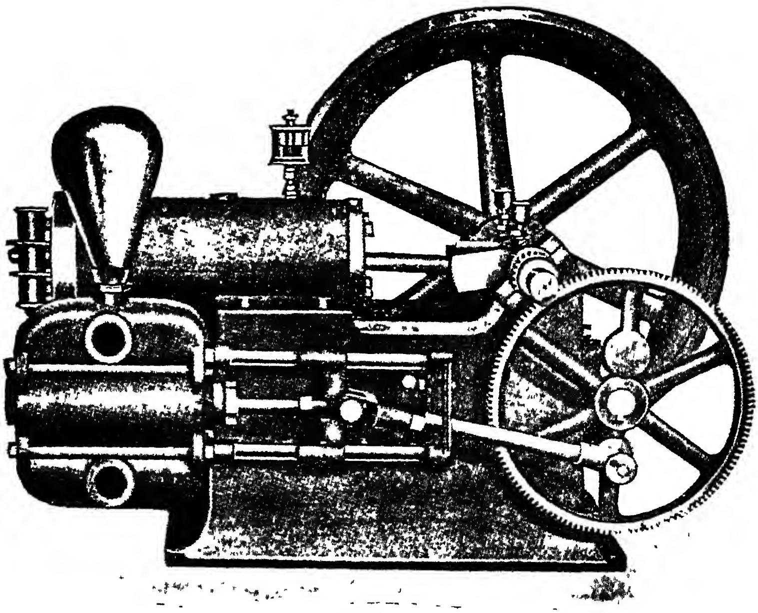


Fig. 262.—Hartig pumping-engine.

valve by holding it open, which prevents a charge. The horizontal engines have an auxiliary exhaust-port uncovered by the extreme forward stroke of the piston. The exhaust-valves are of steel and conical seated. The admission-valves are of the self-acting type, double-conical seated, and control both the air and

gas ports. Engines fitted for using gas are usually fired by porcelain hot-tubes; but nickel tubes may be used if required.

The hot-tubes are placed horizontal on all their engines and so

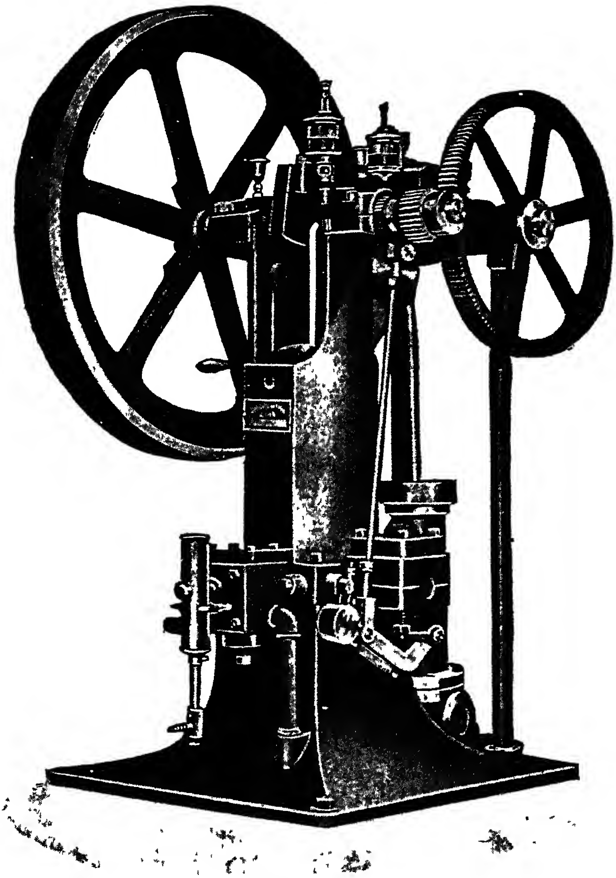


FIG. 263.—Hartig vertical pumping-engine.

arranged that they may be heated to the igniting temperature at any part, to control the time of firing.

Gasoline-engines are usually fitted with electric ignition, of the make and break type, so arranged as to control and vary the time of ignition while the engine is running.

Electric ignition may be fitted to either gas or gasoline-engines,

as desired. With slight alteration of the sizes of ports and valves, these engines work perfectly with acetylene gas. The gasoline-

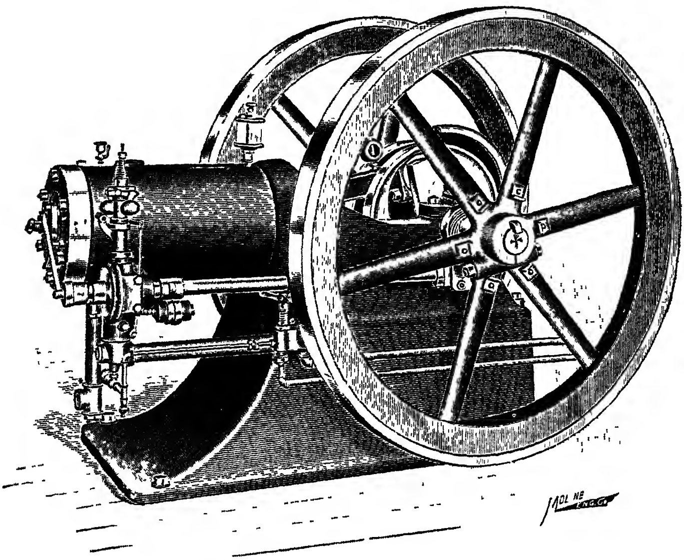


FIG 264.—The R. & V. horizontal gasoline-engine.

engines have a pump-feed from a tank below the engine, or buried outside of a building, the surplus gasoline draining back to the tank. The vaporizer is of the constant-level type with a glass sight-feed body, showing clearly to the eye by a glance that the constant level is being maintained. The feed is by suction and controlled by a needle-valve with graduated disk.

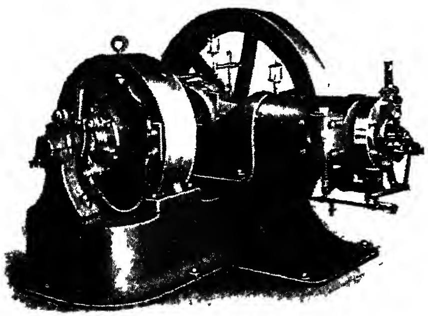


FIG. 265.—Direct-connected engine and generator.

The motors of the Root and Vandervoort Engineering Company, East Moline, Ill., are of the horizontal and vertical four-cycle type, and are well designed for all kinds of power service and for pumping and hoisting. In Fig. 264 we illustrate their

horizontal gasoline-engine, showing the valve-gear and gasoline-pump operated by a side-shaft driven by spiral gears from the main shaft, at half-speed for the four-cycle effect. A fly-ball gov-

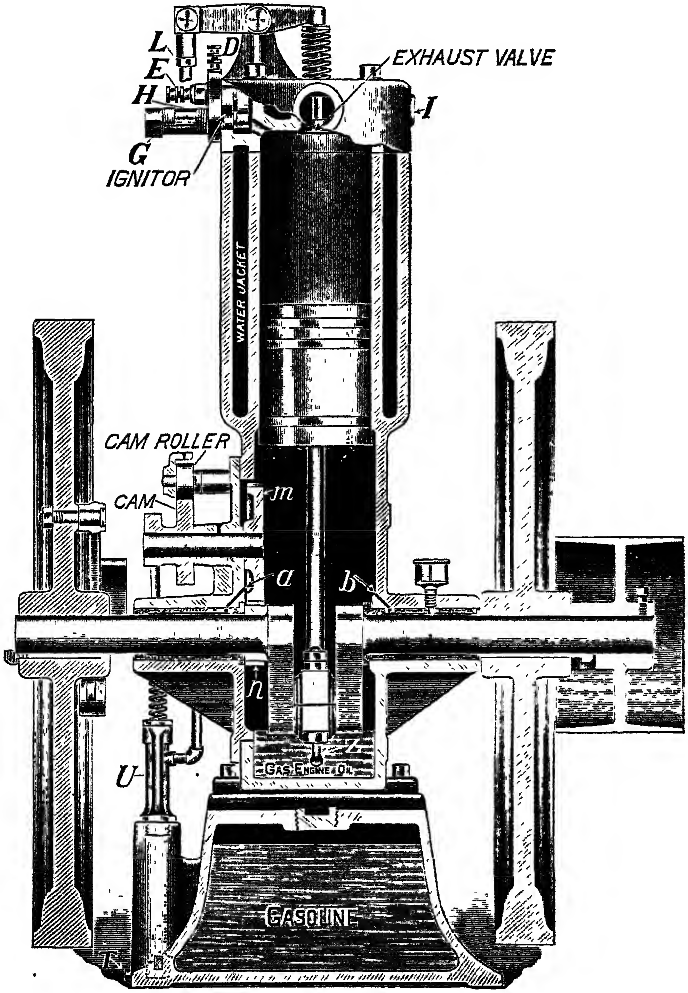


FIG. 266.—Section of R. & V. vertical engine.

ernor driven from the side-shaft controls the flow of gasoline to the atomizer and vaporizer, so that the engine speed is governed by the varying volume of fuel. The ignition is electric, of the

hammer-spark type, operated by push-rod from a crank-pin at the end of the side-shaft, as shown in the cut.

In Fig. 265 we illustrate the horizontal engine, direct connected to a four-pole generator on a substantial base bolted to the engine-base. The running of this engine of eight, fourteen, and eighteen horse-power direct connected to a four and one-half, eight and one-half, and twelve-kilowatt generator of 110 to 120 volts is so steady that the voltage does not fluctuate to exceed one volt.

The vertical engines of this company are of the same cycle type as before described but the arrangement of the valve and pump-gear are made to meet the vertical position of the cylinder. A pair of spur-gears on the inside of the crank-chamber drives a short shaft on which are fixed the exhaust and pump cams. The exhaust push-rod also carries a short igniter-rod, which by a double motion of the exhaust-rod operates the hammer-stroke of the igniter.

In Fig. 266 is illustrated a section of the vertical engine, showing details of the parts.

The pump, operated from a cam on the small shaft, pumps an excess of gasoline to the small constant-level reservoir at the top of the cylinder, and overflows to the main reservoir in the base of the engine, which holds a day's supply. By this means a constant level of gasoline is maintained at the mixer, assuring a uniform charge. The governor of the vertical engine is of the centrifugal type, with a single weight and arm, adjusted by a spring, making a hit-or-miss charge by holding the exhaust open.

MARINE AND STATIONARY ENGINES OF THE HUBBARD MOTOR COMPANY, MIDDLETOWN, CONN.

We illustrate in Fig. 267 a section of the two-cycle vertical motor of this company; its characteristics of construction are similar to the general type of this class of motors. Its movement is simple, complete, with the ignition device driven by a single push-rod connected to a cam-rod and which also carries the plunger of the circulating-pump.

In upper right-hand corner of the cut is shown the quick-acting spark-break device.

The action of the spark is very simple and easily understood. The slide S, which carries both the plunger of the pump P and the spark-trigger T, is moved by an eccentric on the fly-wheel, so that it is at the top of its stroke simultaneously with the piston. When it nears the top, T strikes plunger H and lifts it against spring U,

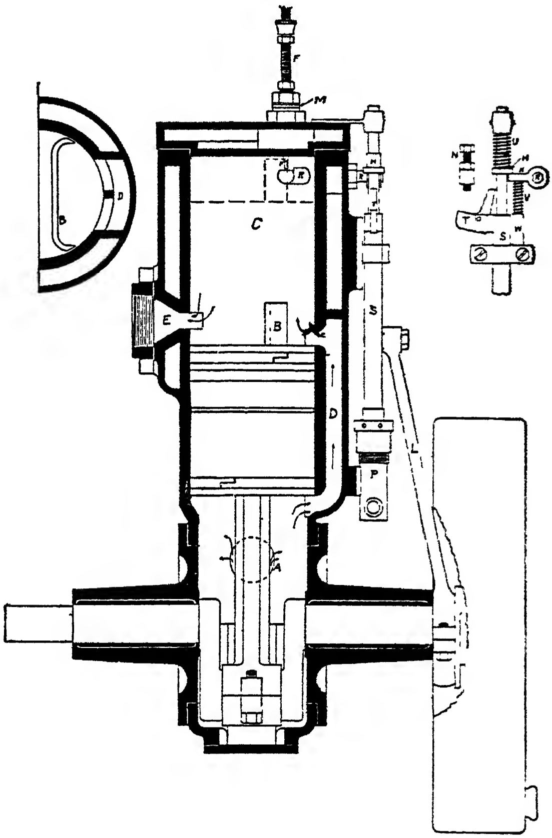


FIG. 267.—Section of the Hubbard motor.

allowing the inside spark-lever R and outside spark-lever K, which are firmly pinned together, to be pressed upward by spring U till R touches F. Then T strikes screw N, causing H to be released and strike K sharply, thus snapping R quickly away from F and making a bright spark. In order to advance the spark, N is screwed down, and to retard it, screwed up.

During the up-stroke of the piston a mixture of air and gasoline is drawn from the mixing-valve through the opening A into the tightly enclosed crank-chamber. At the beginning of the down-stroke the mixing-valve is automatically closed, and when the piston passes the inlet-port D the mixture in the crank-chamber is sufficiently compressed so that it rushes through port D into the

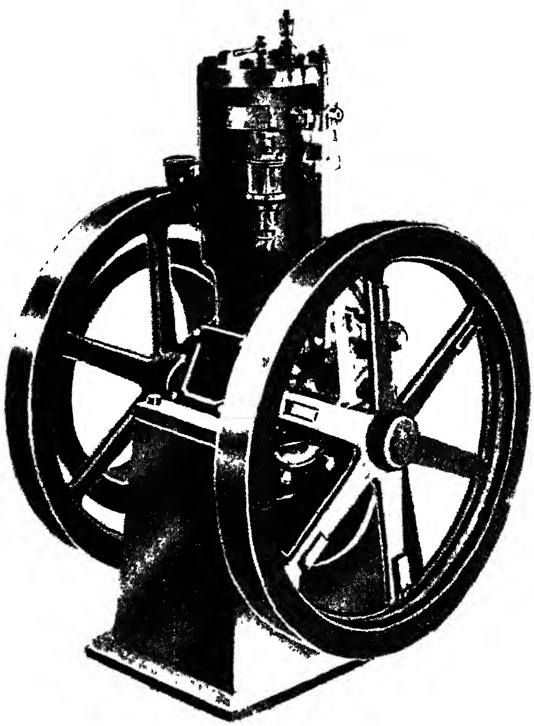


FIG. 268.—Vertical two-cycle motor.

cylinder, where it is deflected upward by the baffle-plate B, and forces out any remaining burnt gases through the exhaust-port E. When the piston goes up again the charge is compressed into the space above the dotted outline of the top of the piston and fired by a spark between firing-pin F and inside spark-lever R. This makes a pressure of about 300 pounds per square inch, which

drives the piston down on its power stroke, at the end of which the charge is exhausted through E when that port is uncovered by the piston.

The single and double cylinder marine motors are of the two-cycle type, with the heads and cylinders cast in one piece and water-jacketed. The four-cylinder motors are of the four-cycle type, with their heads and cylinders cast in single pieces and water-jacketed. The exhaust-valves are operated directly from a cam-shaft in front of the crank-case, and the ignition-gear by a small shaft at the head of the cylinders, driven by an upright shaft and bevel gears from the main cam-shaft.

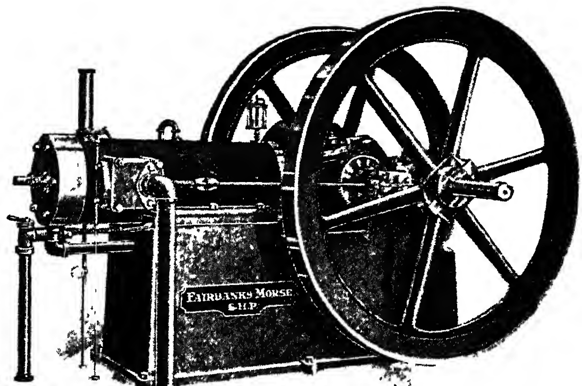


FIG. 269.—Horizontal gas-engine.

In the following figures we illustrate the various models of gas, gasoline, kerosene, crude-oil, and suction gas-engines of Fairbanks, Morse and Company, Chicago, Ill. All the engines of this company are of the four-cycle compression type. The horizontal engines in cylinder units from five to sixty horse-power, and the vertical engines in cylinder units from two to twelve horse-power. The multicylinder engines are built in sizes from 20 to 150 horse-power. Fig. 269 shows the valve side of a gas-engine in which the fuel is regulated by an indexed valve and the speed governed by holding the exhaust open by the action of the governor on the fly-wheel. The gasoline-engine is of the same model, with an

automatic-pump supply of the gasoline-fuel to a constant-level reservoir and overflow to the tank.

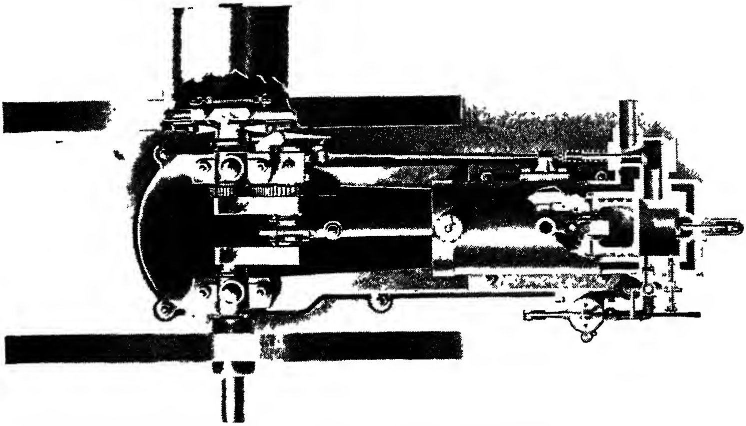


FIG. 2 —Plan of horizontal engine.

In Fig. 270 is shown a plan of the gasoline-engine with the position of the governor, reducing-gear, exhaust push-rod with the cam-lever for regulating, by holding open the exhaust-valve. The starting air-pump is shown at the side of the engine.

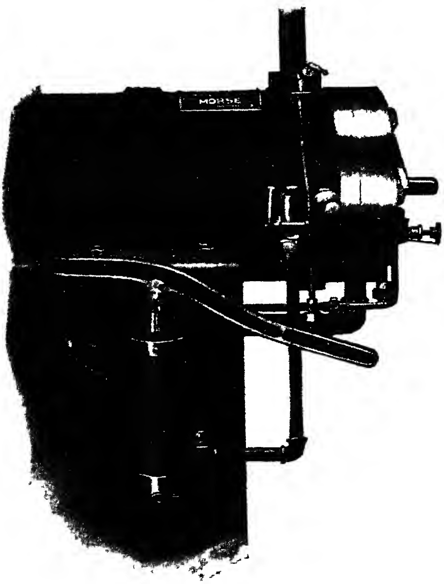


FIG. 271.—The starting pump.

In Fig. 271 is shown the gasoline-engine starting-pump and detonator, by which a charge is forced into the cylinder to be fired by the detonator or by the electric igniter. By this means the engine will start under a half-load without jerk or jar.

The engines, operated with kerosene or crude oil, are fitted with a generator attached directly to the

exhaust-outlet of the engine. The oil is supplied to the top of the generator and is converted into a gaseous vapor which is drawn into the cylinder with the air as an explosive mixture. The generator is provided with a torch-lamp for generating vapor gas for starting the engine.

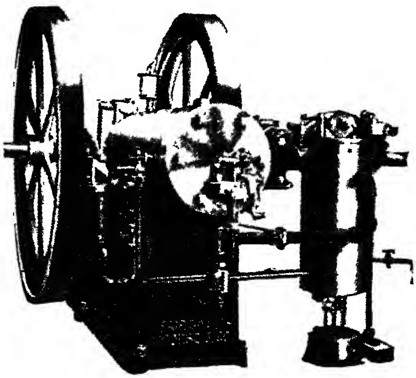


Fig. 272.—Kerosene-oil generator.

In Fig. 273 is illustrated a larger generator arranged for converting the heavy crude oils into a suitable vapor for explosive power. It is constructed on the same lines as the generator for kerosene and with an enlarged heating surface necessary for converting the heavy crude oil.

The oil-feed device is shown on top of the generator, with its pipe connections. A torch-lamp is also used for starting the engine. A pump supplies the oil-feed device with a return of the overflow to the tank.

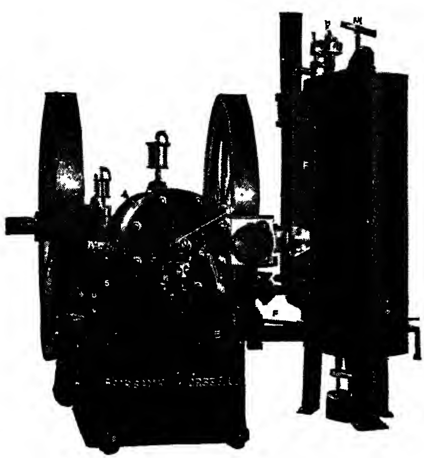


Fig. 273.—Crude-oil generator.

The generator consists of an outer shell surrounding the heating passage, which is so constructed that the exhaust from the engine passes through it. The heat admitted to this chamber is regulated by a by-pass chamber, directing some of the heat straight to the atmosphere before it enters the heat chamber.

Crude oil or kerosene is admitted within the outer chamber at the top. The device used for admitting the fuel is the same as that of the Standard Gasoline-Engine.

As the engine makes the suction or inhalation stroke, there is

a vacuum set up in the generator. This vacuum is placed so as to draw the fuel through the nozzle from which it discharges on the

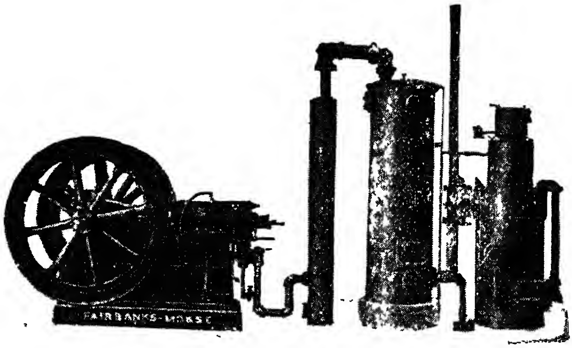


FIG. 274.—Suction gas-plant.

heating surface of the internal heater, and the result is gasification of the oil or kerosene. This gas, of course, is drawn into the engine at the next suction stroke.

The feed-device being automatic, also properly measures the quantity of fuel to be used in the next charge, and with the hit-or-miss governor the exhaust is held open and no suction occurs; con-

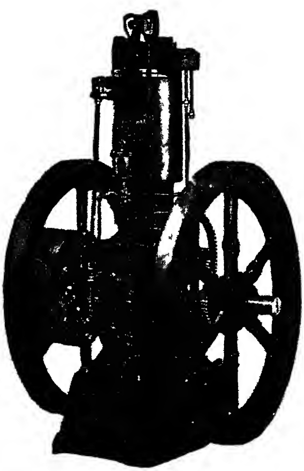


FIG. 275.—Vertical engine.

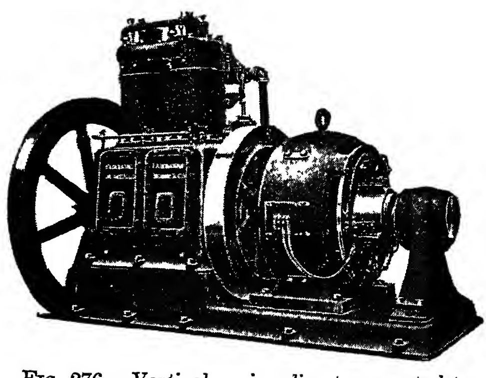


FIG. 276.—Vertical engine direct connected to dynamo.

sequently gas is not drawn from the generator until speed of engine slackens, and the governor releases the exhaust, which is then

closed. With the volume-governor the vacuum is light or heavy in the generator, according to how the fuel is proportioned.

The crude-oil generator is considerably taller or larger than that used for kerosene, the exhaust entering at bottom and continuing through the spiral to discharge at top. Fuel is admitted at top end of the spiral, travelling the entire length while its vapor is being generated.

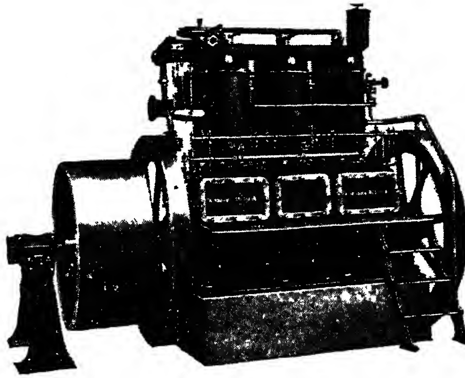


FIG. 277.—150-horse-power vertical three-cylinder engine

Fig. 274 illustrates the gas-engine connected to a suction gas-producer, which consists of a generator in which the gas is made, a small steam-generator in the hot chamber of the gas-generator for supplying moisture to the air entering the gas-generator, a scrubber through which the gases pass for purification, and a tank for a surplus supply to meet the sudden draughts of the engine during the charging strokes. A further description of the details of gas-producers is given in Chapter XXIV.

Fig. 275 shows the single-cylinder vertical model, the details of construction following the same general lines as their horizontal four-cycle type. They are built in two, three, four, six, nine, and twelve horse-power, and are supplied with generators for kerosene when required; otherwise gas or gasoline is the usual fuel.

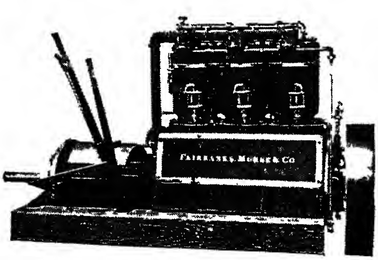


FIG. 278.—Multicylinder marine engine.

Fig. 276 shows their two-cylinder vertical engine, direct connected to dynamo of multipolar type. All their multicylinder engines are supplied with direct-connected multipolar dynamos for electric light or power work.

Fig. 277 illustrates their vertical multicylinder 150-horsepower engine, showing arrangement with out-board bearing and belt pulley.

In Fig. 278 is illustrated their multicylinder marine engine with reversing gear. This type of marine motor is made in units of one, two, three, and four cylinders, from 2 to 100 horsepower. The simplex or single-cylinder engine is of the two-cycle type. All others are four cycle.

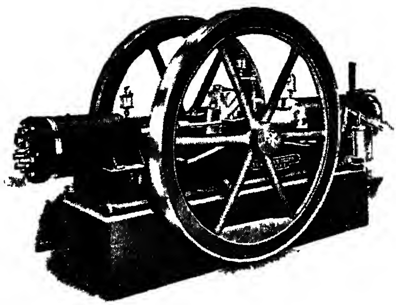


Fig. 279.—Motor air-compressor.

Fig. 279 shows their combined engine and air compressor, with the power and air cylinders arranged tandem or direct connected, and for the larger sized in cross-connected model. These compressors are furnished with all the devices necessary for regulating the motor-speed and compressed-air pressure.

CHAPTER XXI

MARINE MOTORS

THE explosive motor has of late acquired a success in its application for marine power, in which its use has developed a marvellous speed in small craft that has outstripped anything heretofore accomplished by steam-power.

Racing launches and yachts are nearing the 40-mile mark, and their speed limit may be far beyond our earlier dreams; all due to the new element of power. For the accomplishment of this ideal purpose a marine motor must be as compact and light in weight (compatible with strength) as possible, and should be so designed that any part can be adjusted, taken out, or renewed without disturbing anything else, for the quarters in which engines of this type are placed are oftentimes cramped and dark, and accessibility, after reliability, is a prime necessity. When these points are given proper consideration in the design and construction of marine motors, far greater success and pleasure will attend their use than has been experienced in the past.

Yet the era of advancement during the past decade has had its salient points of interest and pleasure in sailing speed, and the present designs of marine motors are fast approaching the perfection of action and convenience of management so desirable in the motor service for pleasure craft.

MARINE ENGINES AND THEIR WORK

The oft-repeated inquiry as to the proper size of motor and wheel for certain-sized boats has induced the author to gather, in the following table, the leading points for moderate-speed boats, as derived from a leading yacht and launch motor-boat concern. The conditions are much too high for auxiliary power for sailing craft, and too low for racing craft, which in all cases requires special

APPROXIMATE SIZES OF ENGINES, PROPELLERS, AND BOATS.

Size.	Cylinder.		Revolutions.	Propeller-Wheel.		Launch or Boat.	
	Diam.	Stroke.		Diam.	Pitch.	Length	Beam.
3 H. P. Single-cylinder	5 in	7 in.	480	16 in.	24 in.	18 ft	5 ft.
4 " " "	5½ in.	7 in.	450	18 in.	26 in	25 ft.	6 ft.
5 " " "	5½ in.	9 in.	425	20 in.	28 in.	28 ft	6½ ft.
6 " " "	6½ in.	9 in.	400	21 in.	28 in.	30 ft	7 ft.
6 " Two-cylinder	5 in	7 in.	475	18 in.	26 in.	30 ft.	7 ft
8 " " "	5½ in.	7 in.	400	23 in.	32 in.	32 ft.	7½ ft
10 " " "	6½ in.	9 in.	410	26 in.	34 in.	35 ft	8 ft.
16 " " "	7½ in.	11 in.	325	30 in.	38 in.	40 ft.	8½ ft
25 " " "	9 in.	13 in.	300	34 in.	48 in.	45 ft	9 ft
16 " Three-cylinder	6½ in.	8 in.	380	28 in.	38 in.	40 ft.	8½ ft.
16 " Four-cylinder	5½ in.	7 in.	375	28 in.	35 in	40 ft	8½ ft.
20 " " "	6½ in.	9 in.	360	30 in.	40 in.	42 ft.	8½ ft.
32 " " "	7½ in.	11 in.	330	36 in.	48 in.	48 ft.	9½ ft.
50 " " "	9 in.	13 in.	300	40 in.	54 in.	50 ft.	10 ft.

design of boat lines and allotment of power as well as of size and pitch of screw. The approximate speed of launches and larger boats as scheduled in the above table may be obtained by deducting from 20 to 25 per cent. of the product of the revolutions per minute and the pitch of the wheel in feet and decimals which gives the speed in feet per minute. Multiply this product by 60 and divide by 5280 for the miles per hour, or divide the first product by 88, which is $\frac{5280}{60}$, a shorter way.

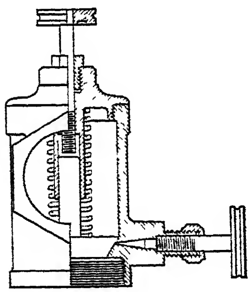


FIG. 280.—Atomizer.

The motors of the Bridgeport Motor Company, Bridgeport, Conn., are of the marine and stationary two-cycle type and are of compact and simple design. The ignition by hammer break-spark and the circulating-pump are both operated by the pump-rod from a cam on the motor-shaft, the igniter being a separate rod lifted by a trip-block on the pump-rod and let go by contact with an adjusting timing-screw. The gasoline is fed to the crank-chamber by an atomizing carbureter with an adjusting needle-valve opening on the seat of the inlet air-valve with an adjusting screw to regulate its lift. The feed to the cylinder is regulated by a revolving perforated damper as shown in the drawings (Figs. 281 and 282), which are to a scale for small-sized motors.

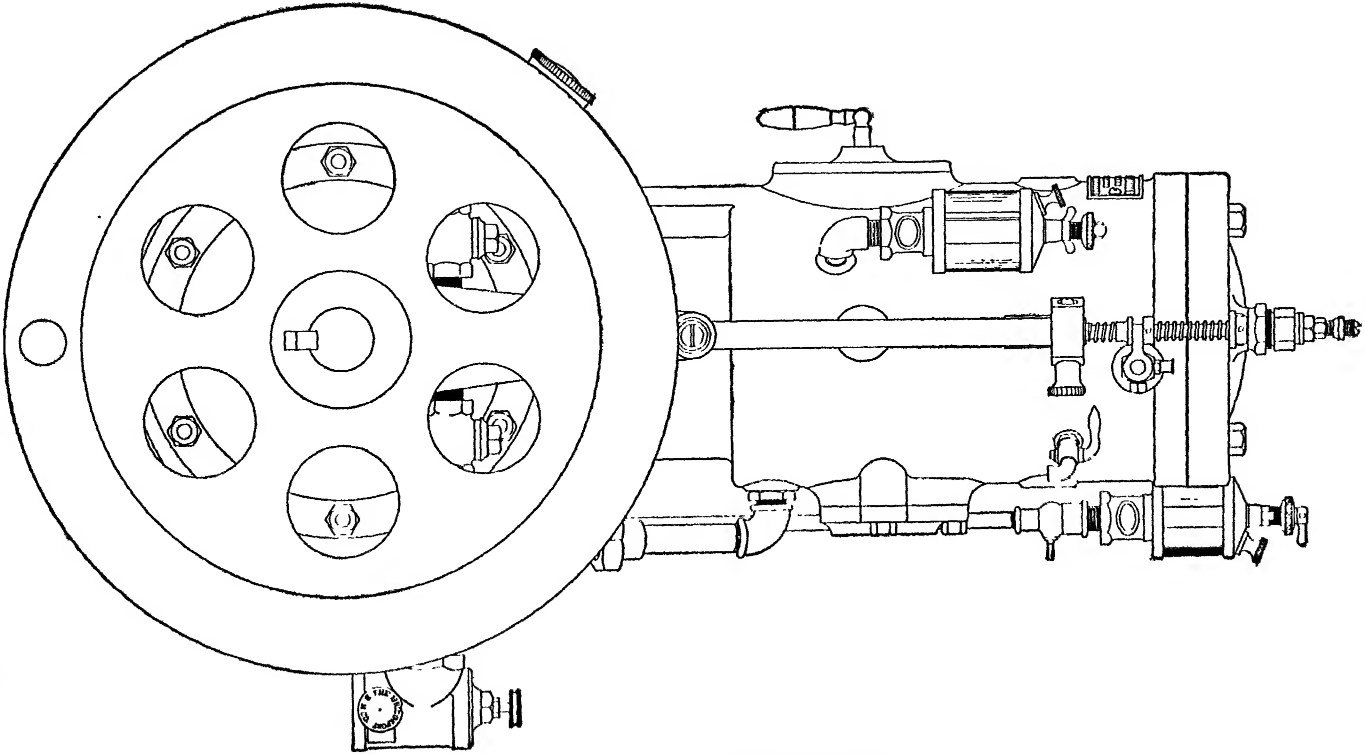


FIG 281.—Front view, Bridgeport motor.

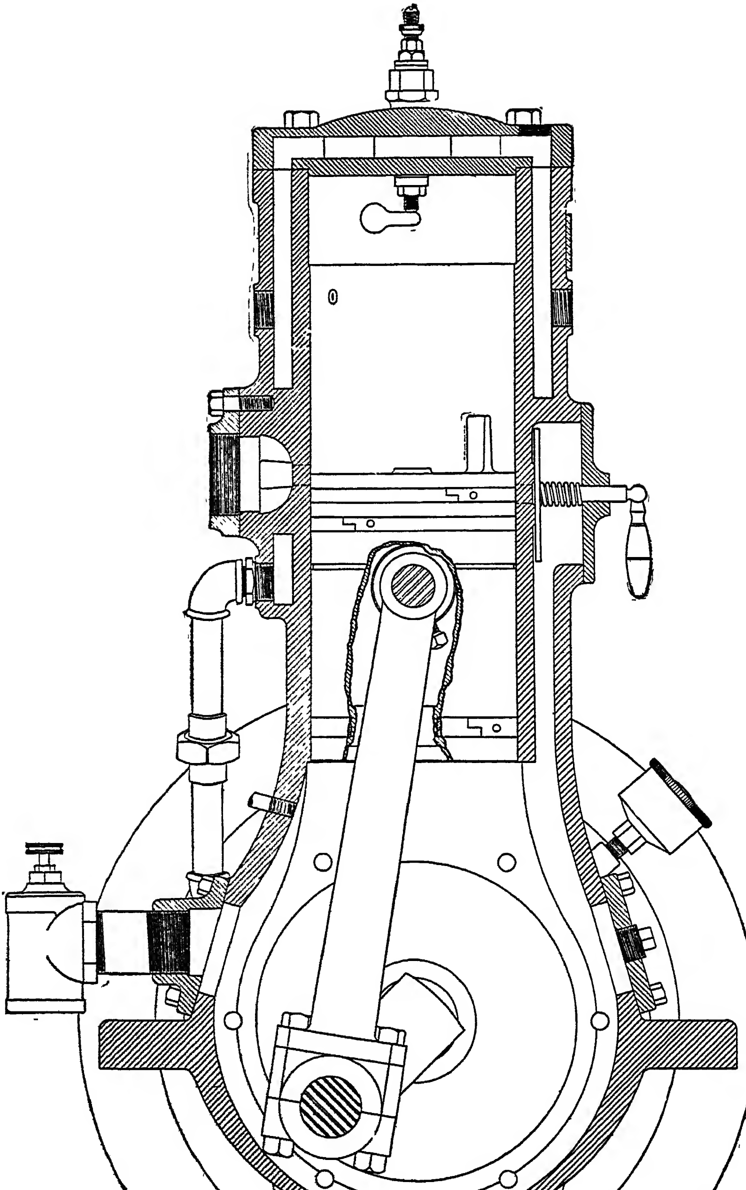


Fig. 282.—Section, Bridgeport motor.

By this double adjustment the charge-mixture is regulated in its proportions in the crank-case, and the quantity of each charge is also regulated for the speed of the motor.

SOLID AND REVERSING PROPELLERS

The Bridgeport motor runs equally well in either direction, dispensing with the necessity for a reverse clutch or reversing propeller, except in the larger sizes. With a solid propeller-wheel, in any size up to six and one-half horse-power, if it is desired to reverse, the switch is thrown off as in stopping engine, and when the engine fly-wheel is near to last revolution and nearly on centre, switched on again, and engine is thus reversed without stopping.

SPECIFICATIONS OF BRIDGEPORT MARINE GASOLINE-ENGINES.

Engines	1½ H.P.	2½ H.P.	3½ H.P.	5½ H.P.	6½ H.P.	8 H.P.	12 H.P.	20 H.P.
Cylinders, number	1	1	1	1	1	1	2	3
Bore, inches	3¼	3¾	4½	5¼	5½	6¼	5½	5½
Stroke, inches	3½	4	5	5½	6½	6½	6½	6½
Revolutions per minute.	600	500	475	450	425	400	400	400
Diameter balance-wheel, inches	12	13	15	17	18½	18½	22	22
Diameter engine-shaft, inches	1	1⅛	1¼	1⅜	1¾	1⅞	2	2
Size of base, inches	7½x10½	8x12	9x13½	12x16½	13x18	13x18	19½x26	19½x38
Height of engine above shaft line, inches	12½	14	16½	21½	23½	23¾	24	24
Weight, pounds	125	170	210	415	485	575	1,000	1,300
Diameter propeller-shaft, inches	⅝	¾	1	1¼	1¼	1¼	1½	1½
Diameter propeller-wheel, inches	12	14–16	15–18	16–20	18–22	20–24	22–26	24–26

The above dimensions are given for the study of all desiring to fit up a launch. The following are the boat dimensions suitable for the horse-powers in the above table of motor dimensions.

Dimensions of Stock Sizes.	Standard Models.					Comfort Models.	
Length, over all	18 ft.	22 ft.	25 ft.	28 ft.	30 ft.	17 ft.	22 ft.
Beam, extreme.	5 ft.	6 ft.	7 ft.	7 ft	7 ft.	7 ft.	7 ft.
Depth, least.	25 in.	27 in.	30 in.	30 in	36 in.	24 in.	27 in.
Draught	20 in.	22 in.	27 in.	27 in.	30 in.	20 in.	22 in.
Engine, horse-power	2½	3½	6½	6½	6½	3½	6½

GASOLINE MARINE MOTORS OF THE YACHT, GAS-ENGINE, AND LAUNCH COMPANY, PHILADELPHIA, PA.

The motors of this company are of the four-cycle type in units of two and four cylinders. The bed-plate and housings are made of an alloy of alumina and magnesium, called by the company

"alumagnia," which has a tensile strength equal to wrought iron and lighter than aluminum. This, with a sheet-metal water-jacket, brings the weight of a two and one-half horse-power "Baby Crown" marine motor at 120 pounds.

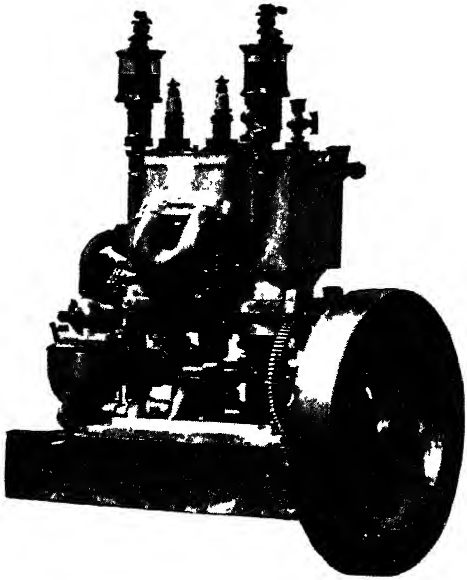


FIG 283.—"Baby Crown," 2½ horse power.

The cylinders are set on stanchions, which leaves an open space for observation and adjustment of the running parts. The carbureter is of the float-feed type with a separate pipe to each cylinder. Ignition is jump-spark, with Herz timer and soot-proof plugs.

The company also builds a fine class of launches, racing boats, and cruisers, with or without auxiliary sails. In Fig. 284 we illustrate their pleasure launch with stanchions and awnings.

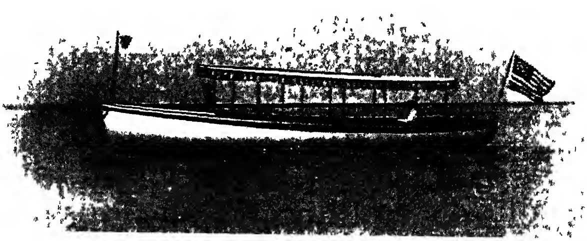


FIG. 284.—The pleasure launch.
"Debutante," 35 feet by 6 feet 9 inches, 16 horse-power, and speed of 12 miles per hour.

MARINE MOTORS AND LAUNCHES OF E. H. GODSHALK AND COMPANY, PHILADELPHIA, PA.

We illustrate in Fig. 286 a light-weight, high-speed marine motor of the two-cycle type, model B, of the above company, built in units of two and four cylinders. Also in double units with the reversing-gear between the units, an innovation upon ordinary practice with many conveniences in operating the motor. As the two-cycle engine will run in either direction by simply changing the lead of the spark, the forward engine may be run in one direction, and the after engine in the other; or the forward engine may be used to start the after engine in the reverse direction, and the forward engine then cut out. By disconnecting the two engines the forward engine may be started by hand and then used to start the after engine by operating the clutch, thus avoiding the use of a starting device.

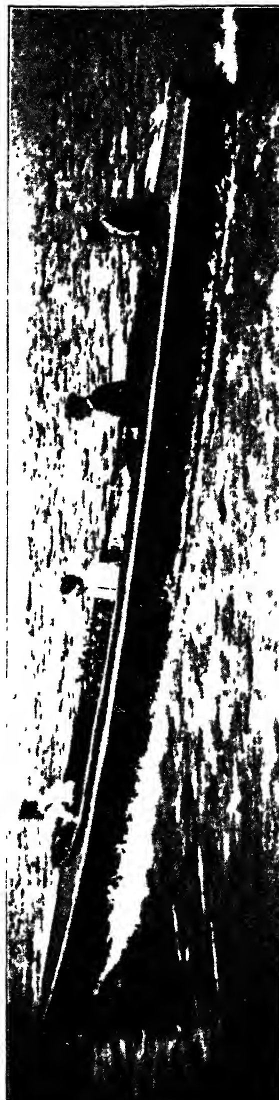


FIG. 285.—"Unique" racing launch of the Yacht, Gas Engine, and Launch Company, Philadelphia, Pa. Length, 35 feet; beam, 4 feet 10 inches. 20-horse-power "Crown" engine, speed, 17 miles per hour. The hull of this racer is of ⅞-inch teak and calked with their patent copper calking, which never leaks.

The principal features of this engine are that the crank-cases are of nickel aluminum, so treated as to be unaffected by the action of salt water, and the cylinders are of cast steel. The water-jackets are separate from the cylinders and are made of seamless drawn-steel shells. The vaporizer is of the compensating type, needing no adjustment for changes in temperature, or in the

speed of the engine. The engine has absolutely no valves, as it is of the three-port type, the inlets to the crank-cases being opened and closed by the piston. This form is found better adapted to high speeds than a check-valve. Ignition is of the jump-spark type, the timer being driven by a silent chain and the timer-shaft supported on a bracket at about one-half the height of the engine. The spark-plugs are entirely enclosed in a moisture-proof shield. The engine is twenty-one inches high from the centre of the shaft to the top of the spark-plug shield, and the forward engine is forty-two inches long from the centre of the coupling to the outside of the fly-wheel. The approximate weight of the two engines combined, exclusive of the reverse gear, is 600 pounds, and at 950 revolutions per minute, which is the normal speed of the engine, it will develop between 60 and 65 brake horse-power.

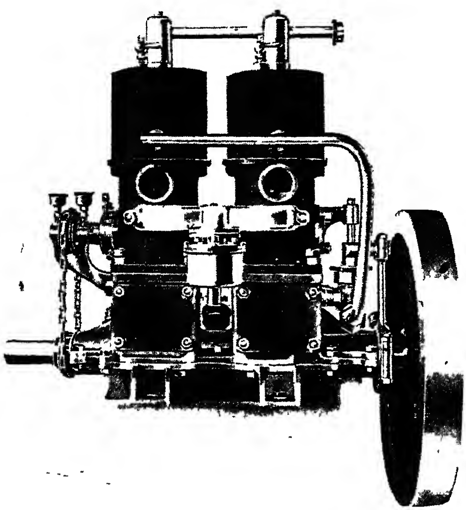


FIG. 286.—Two-cylinder, $4\frac{1}{2} \times 5$, 15 horse-power, 900 revolutions per minute.

The manufacturers build a number of different sizes on this same general design. The smallest of these is $3\frac{7}{8}$-inch bore by 4-inch stroke, developing $4\frac{1}{2}$ horse-power per cylinder. A second size is $4\frac{1}{2}$-inch bore by 5-inch stroke, developing $7\frac{1}{2}$ horse-power per cylinder. The largest size is $5\frac{1}{8}$-inch bore by 6-inch stroke, developing 11 horse-power per cylinder. The normal speed at which these three sizes is rated, is 950, 900, and 850, respectively.

Marine motors of the J. J. Parker Company, Fulton, N. Y., are of the two-cycle type, of light yet strong construction, suitable for the lightest rowboats; a simple design, taking its fuel-mixture from the crank-chamber with a regulating-valve in the passage. A pump driven by a cam on the main shaft supplies water to the

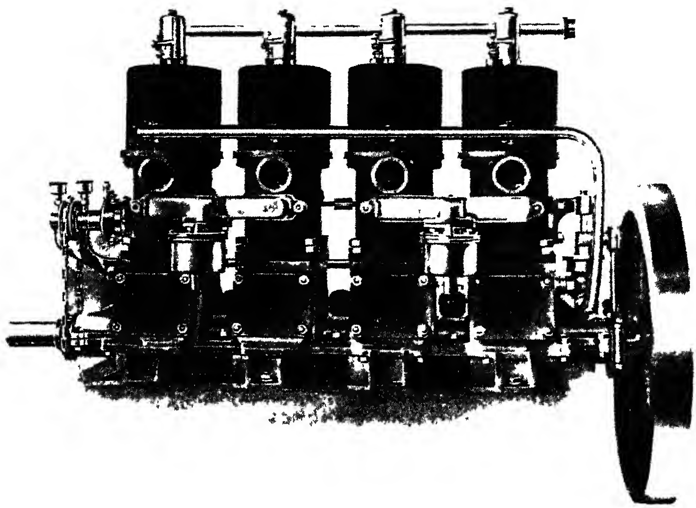


FIG. 287.—Four-cylinder, $4\frac{1}{2} \times 5$, 30 horse-power. 900 revolutions per minute; weight, 400 pounds E. H. Godshalk & Co. Philadelphia, Pa.

cylinder-jackets. The propeller is of the reversing type, as shown in the cut. The motors are built in units of one, two, and three cylinders, from one and one-half to fifteen horse-power. The one-and-one-half-horse-power motor is suited for sixteen and eighteen

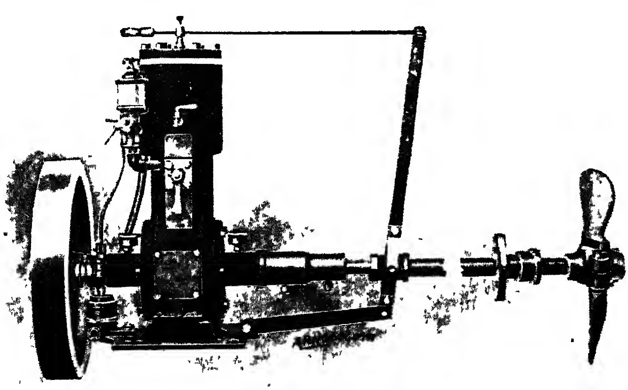


FIG. 288.—Light-weight marine motor. J. J. Parker Co., Fulton. N. Y.

foot boats; three horse-power, for twenty-foot boats; five horse-power, for twenty-five-foot boats, and the ten-horse-power, double-cylinder, for boats of twenty-eight to thirty-five feet, and the fifteen-horse-power three-cylinder motors for boats from forty to fifty feet in length.

MARINE MOTORS OF THE STANDARD MOTOR CONSTRUCTION COMPANY, JERSEY CITY, N. J.

We illustrate in Fig. 289 the six-cylinder Standard marine motor of this company. The cylinders are 8 inches in diameter, 10-inch stroke, and the motor runs 600 revolutions per minute, driving a propeller 36. inches in diameter. The "Standard" is of

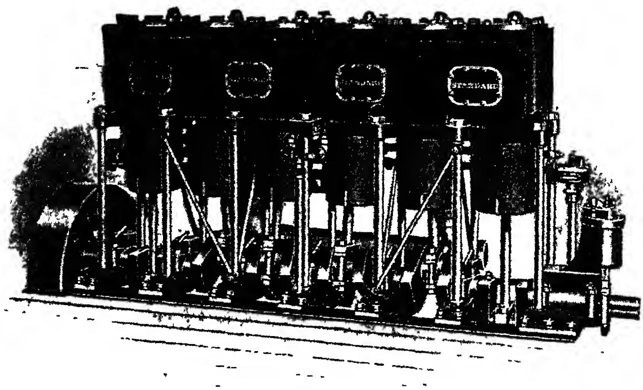


FIG. 289.—The "Standard" 100 horse-power motor.

the four-cycle type and reversed by shifting the valve motion; receives the explosive fuel through a single atomizing vaporizer, with a controlling-valve and index.

The motor is started by compressed air, and, having no dead centres, instantly starts on opening the compressed-air valve. A small air-pump keeps an air-tank at sufficient pressure for starting several times without continuous running.

The "Standard" racing launch, with the above motor, has a speed capacity up to thirty miles per hour.

ENGINES AND TRAWL BOATS OF THE MIANUS MOTOR WORKS MIANUS, CONN.

The above works are largely engaged in fitting auxiliary motors to yachts, which are a great comfort to yachtsmen when the wind fails.

Their trawl-boat motors, not only drive the boat, but also hoist the trawls by a double-drum chain-hoist operated as re-

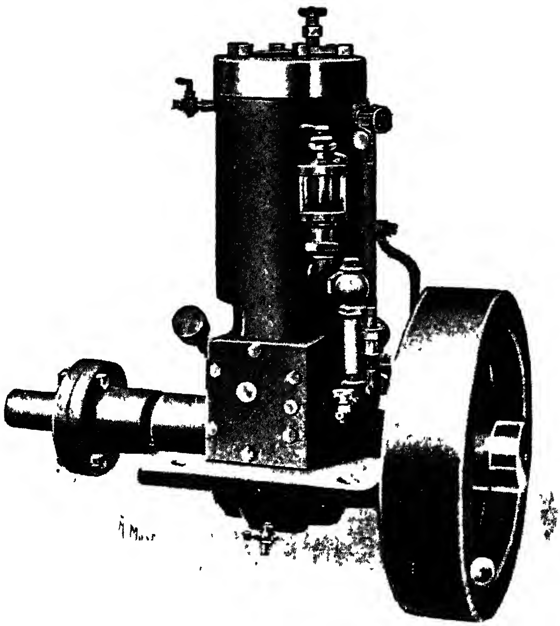


FIG 290.—Two-cycle marine motor.

quired by a clutch and lever. Light-draught twin-screw boats are a great convenience in shallow-water sporting, are one of the specialties of these works. All of their motors are of the two-cycle type, with a snap break-spark with a regulating adjustment for timing the spark, under control by a small hand-lever; altogether one of the most simple and compact designs of this type of motor. A water-circulating pump is attached to the lower end of the igniter push-rod and operated by the same cam that operates the igniter.

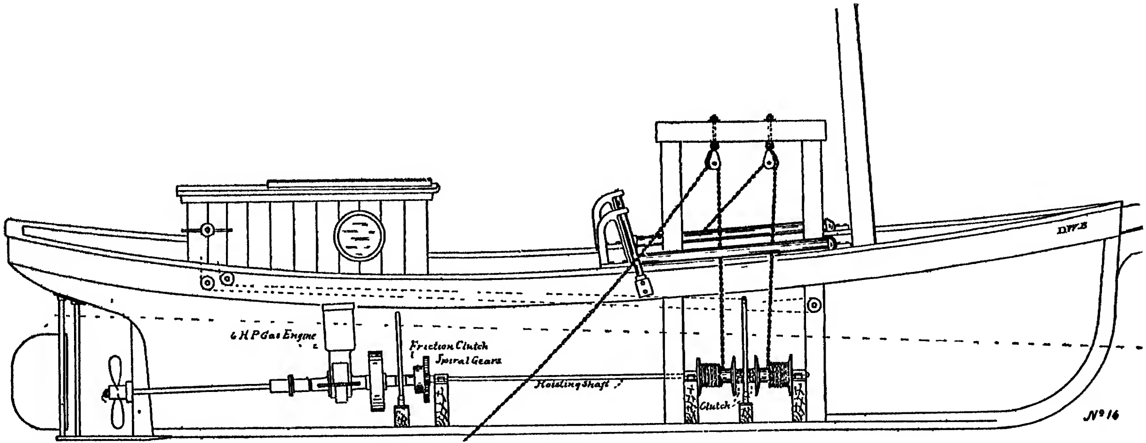


FIG. 291.—Oyster boat, motor and hoist.

This cut represents an oyster sloop 32 ft. long and 11 ft beam. The boat was not originally intended for power, and is of the type usually found in Long Island Sound, and in Great South Bay, on the south side of Long Island. It is equipped with one 6-horse-power two-cycle gasoline-engine. The engine is connected to one double-drum hoister, built especially for the 6-horse-power engine It is so designed that both drums are placed on one shaft. This does away with one set of gears and considerable extra machinery, which is necessary when connected in the usual way. This greatly simplifies the hoister, and reduces the cost considerably, but does not decrease efficiency of hoist in any respect.

This is a one-man boat, *i e.*, one man can run the engine, operate the hoist, and steer the boat.

The hoister consists of two drums 12 inches in diameter, 10 inches long, and will hold 100 feet of $\frac{1}{4}$-inch chain, hoisting-shaft, $1\frac{5}{8}$ inches in diameter; tube to cover the shaft; set of side-rollers, friction-clutch, all necessary axle-boxes, levers, fittings, etc.

MARINE MOTORS OF HALL BROTHERS GAS-ENGINE WORKS, PHILADELPHIA, PA.

The aim in the design of these motors is to provide a motive power that will maintain its wearing properties, and stand the abuse

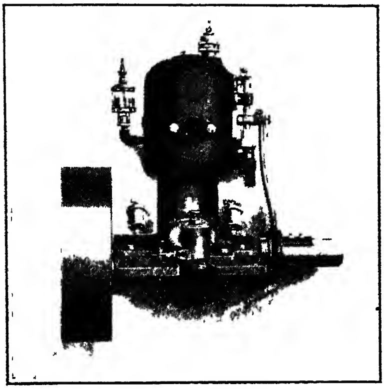


FIG. 292.—3½-horse-power 2-cycle motor. Exhaust side

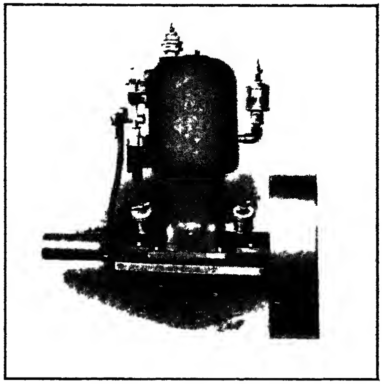


FIG 293 —3½-horse-power 2-cycle motor. Water side.

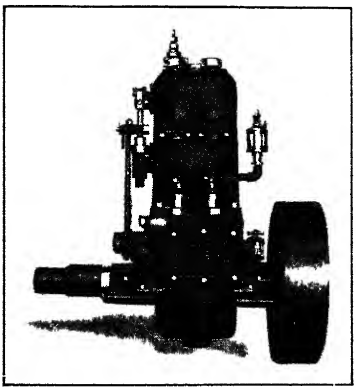


FIG. 294.—5-horse-power 4-cycle motor. Valve side.

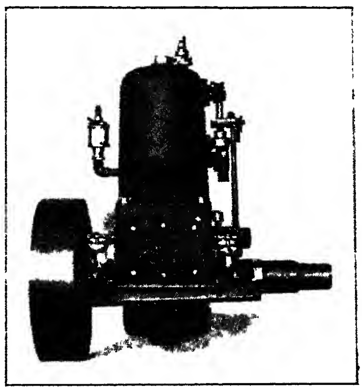


FIG. 295.—5-horse-power 4-cycle motor. Water side.

that this class of motors is subjected to in the hands of unskilled operators.

These motors are built on simple, compact, and durable lines, and with lightness compatible with wear and smooth running.

Solid-head cylinders, steel pistons. Float-feed carbureter, regulation by throttle and spark-timer.

All the motors of this company have a great range of speed.

In Fig. 296 is illustrated the single-cylinder marine motor of the two-cycle type. On the side of the crank-case is shown the carbureter and the air-inlet device, also the inverted water-pump with a direct-drive from a cam on the shaft. The details of the

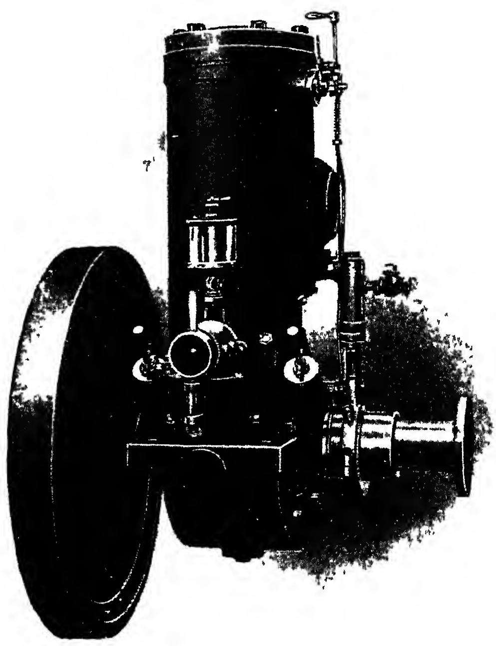


FIG. 296.—Lozier two-cycle marine motor.

action of these motors of the Losier Motor Company, Plattsburg, N. Y., are illustrated and described in Chapter XVI.

The ignition is by the hammer-break system, with both electrodes in a single, easily removed plug, which also has the battery-switch attached. These motors are built in sizes of three, five, and seven and one-half horse-power, and of models designated as A, B, and C type, which relates principally to the arrangement of the ignition and controlling parts. The carbureter is of the float-feed type, with a governor to control the gasoline-charge.

The larger Lozier marine motors are of the four-cycle type, with four cylinders, and are a model of compactness and lightness. The twenty-five-horse-power motor, with the bed-plate, fly-wheel, and reversing-gear weighs 850 pounds, or only thirty-four pounds per horse-power.

In the four-cycle type of the Lozier motors the admission-valves, as well as the exhaust-valves, are mechanically actuated, and the principal governor, of the ball type, operating on the

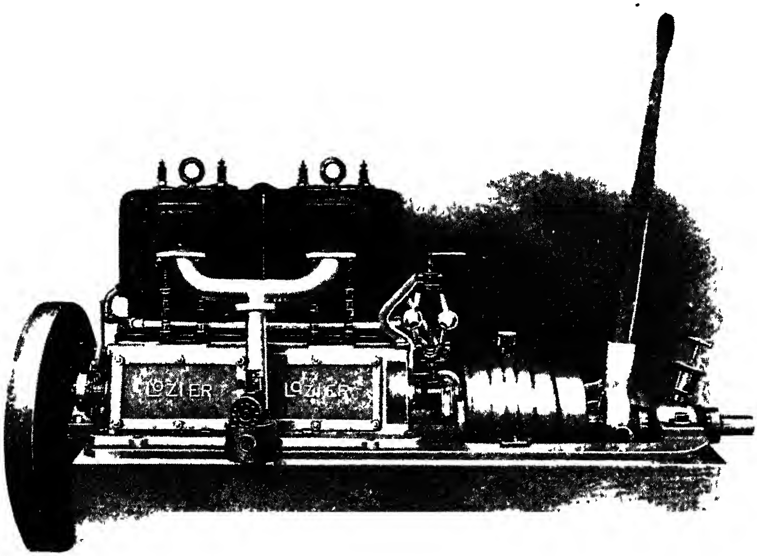


Fig. 297.—Four-cycle auto-marine motor, four-cylinder, 25 horse-power.

admission-valves throttles the gas as it enters the firing-chamber. This governor automatically responds to any change in the load, and is a feature which cannot be applied to a motor, the admission-valves of which are operated by suction. A valuable point to be noticed in connection with this governor is the fact that the speed may be reduced, with a corresponding reduction in the amount of gasoline consumed.

The time of ignition may be changed by means of the timing-lever, which enables the speed of the motor to be controlled at the will of the operator, making a great range of speed possible.

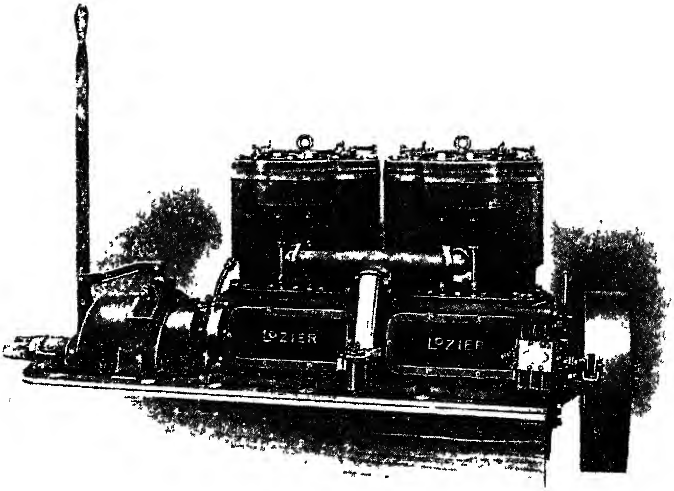


FIG. 298.—Four-cycle auto-marine motor, four-cylinder, 40 horse-power.

The admission and exhaust-valves are on opposite sides of the motor, giving it a well-balanced appearance. The valves, being mechanically lifted, are positive in action, and there can be no sticking or fouling, as is liable to be the case where valves are

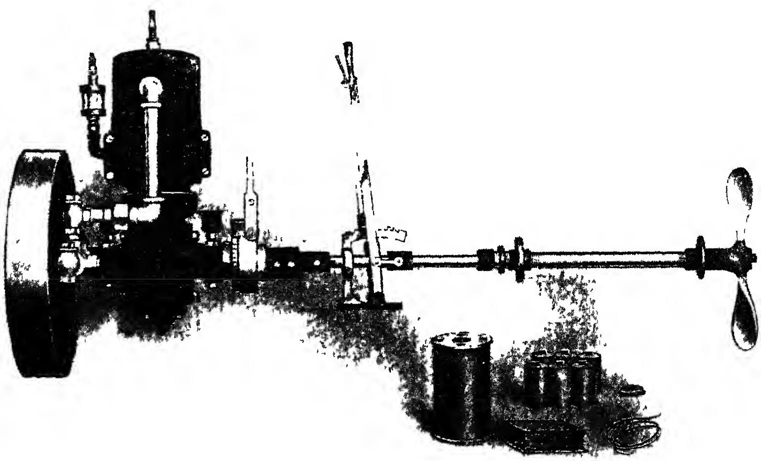


FIG. 299.—Cushman marine motor and equipment.

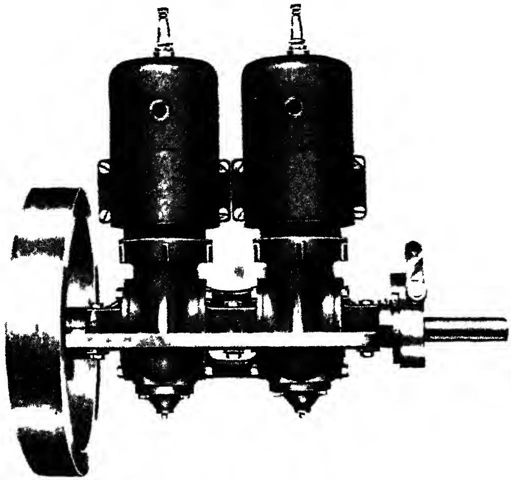


Fig 300 —Two-cylinder high-speed automobile motor.

operated by suction. By unscrewing the covers, which are set in the cylinder-heads directly over the valves, they may be easily removed and examined. The valves are of nickel-steel and not easily affected by the intense heat, thus removing one of the prevalent sources of trouble with four-cycle motors.

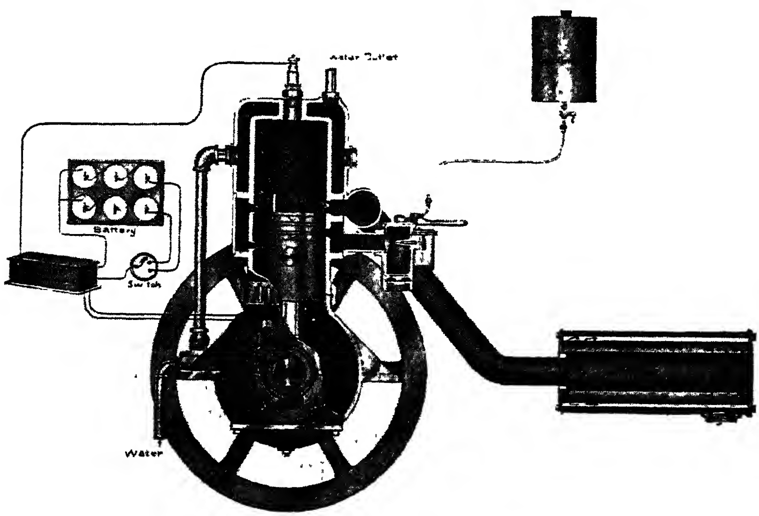
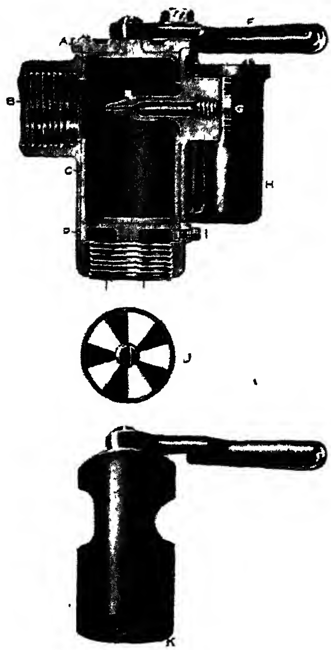


Fig. 301.—Section of motor, wiring, and muffler.

The exhaust-valves may be lifted by means of a single hand-lever, which relieves the compression and allows the fly-wheel to be turned in starting with very little exertion. A safety locking-device makes it impossible for the operator to start the motor without setting the timing-lever at "safety."

The igniter mechanism is of the make-and-break type. The firing-plug for each cylinder contains both the firing-pin and



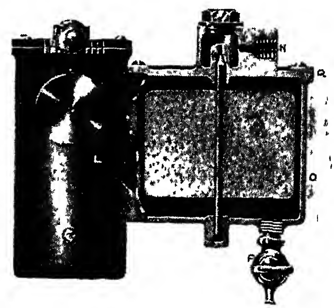


FIG. 302.—The carbureter

A. Cover of mixing-chamber. B. Gas-outlet. C Throttle-valve. D. Adjustable-disk. E Nozzle. F Throttle-lever which controls speed. G Needle-valve. Controls proportions of mixture. Easily removable if nozzle becomes clogged. H. Float-chamber. I. Set-screw to hold disk in position. J. Disk. K. Throttle with disk removed. L Pipe which carries gasoline from float-chamber to nozzle. M. Float-valve. N. Feed-pipe. O. Float-chamber. P. Drain-cock. Q. Float-chamber cover.

rocker-arm, and occupies a central position in the cylinder over the firing-chamber.

In Fig. 299 we illustrate the high-speed marine motors of the Cushman Motor Company, Lincoln, Neb. In the design of these motors, simplicity in the arrangement of all their parts has been followed, with the result that a light-weight, high-speed motor, suitable for any service of the pleasure or racing boat, has been attained. Their product is in one and two cylinder motors of two, four, seven, eight, and fourteen horse-power, and stationary motors of three and six horse-power. Fig. 300 represents their

two-cylinder automobile motors of eight and fourteen horse-power. In Fig. 301 are shown some peculiar details of construction worthy of note. The atomizing-carbureter discharges its gasoline and air-mixture into an annular chamber at the lower end of the cylinder, where it is perfectly vaporized, and enters the cylinder on the opposite side through pressure from the crank-chamber and ports in both cylinder and piston, opened at the charging end of the stroke.

The Cushman igniter is so constructed as to form a make-and-break for either non-vibrator or vibrator coils. It is placed on the main boxing of the engine and revolves on the steel ball-bearing J around a cam H placed on the shaft G, which changes the posi-

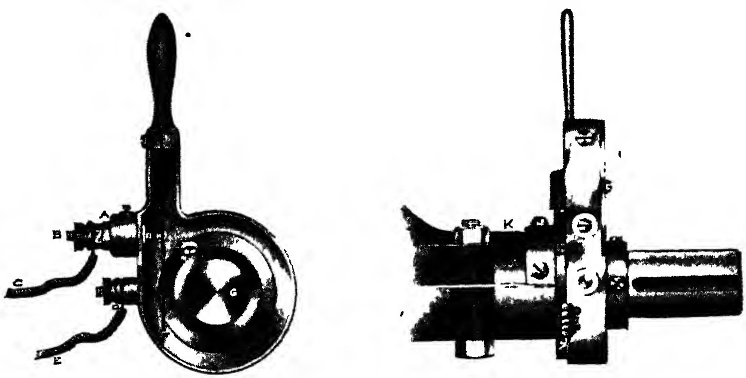


Fig. 303 —The Cushman igniter.

tion of the spark, and is usually termed a spark-shifter. The cam employed for this purpose is a hardened-steel roller on a steel pin which revolves with the shaft. This roller comes against a spring F carrying one of the contact-points. The other contact-point is fastened to an insulated screw, the insulation being of hard fibre held in place by the igniter-frame.

The igniter may be moved to any desired point while the engine is running, and remain in that position until moved again, being held by a rack-and-spring plunger. C, B and E, D are the wires and posts forming the circuit.

In Figs. 304 and 305 we illustrate the details of the marine gasoline-engines of the Smalley Motor Company, Bay City, Mich.

The method of admitting the charge at the top of the cylinder through a by-pass from a port in the piston is a distinct feature of the Smalley motors, and a valuable one in defining the boundary of the new charge and the exhaust of the last explosion.

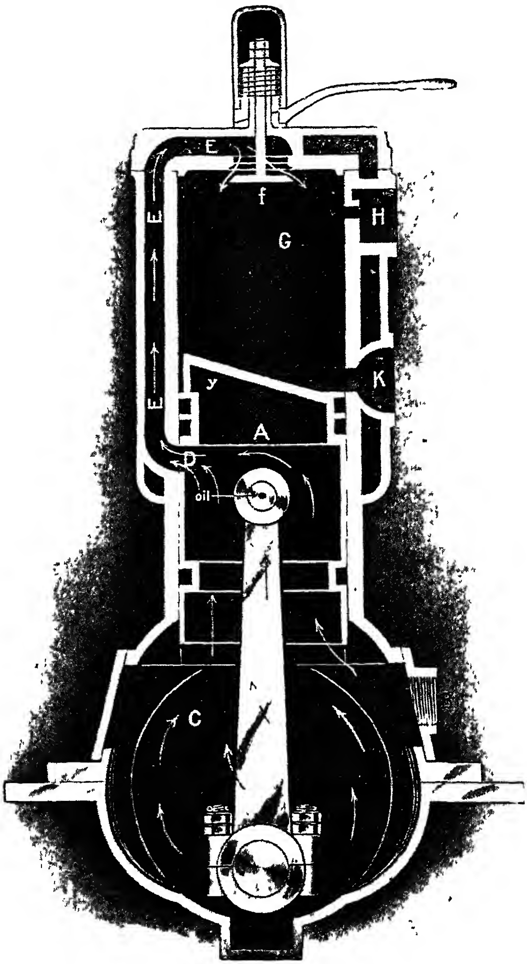


FIG. 304.—Section showing charging by-pass.

When the piston moves upward a charge of vaporized gasoline is drawn through the vaporizer-inlet B into the crank-chamber C. When the piston moves downward this vapor is compressed in the

crank-chamber C. As the piston reaches the lower end of its stroke it brings the admission-port D (Fig. 304) in the hollow piston opposite the by-pass opening E E E, thus allowing the vapor-charge in the crank-chamber to pass into the upper end of cylinder or com-

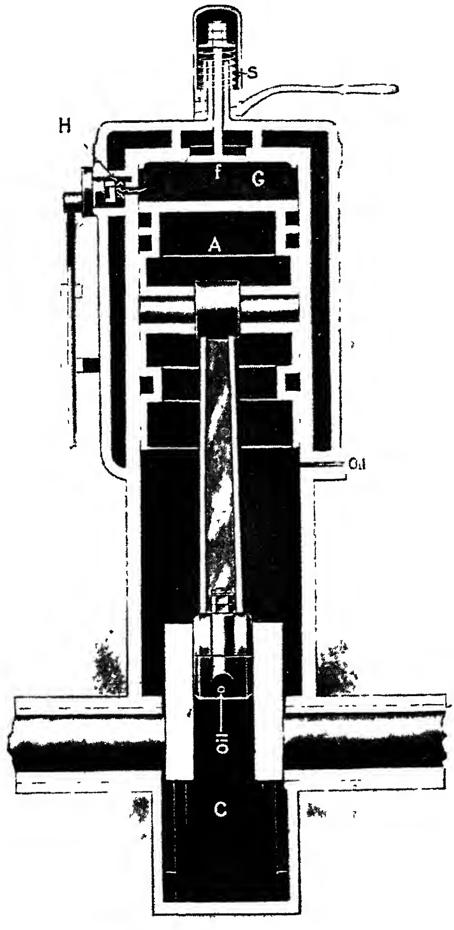


FIG. 305.—Section of ignition-chamber and break-spark device.

bustion-chamber G, through the admission-valve f, which is forced open. At the beginning of the upward stroke of the piston, the valve f is closed by the tension of the spring S, and the gas thus

held in the chamber G is compressed by the piston moving up against it. The charge is then ignited by an electric spark in the ignition-chamber H (Fig. 305). The expansion caused by the explosion of this gas forces the piston downward. As the piston passes down-

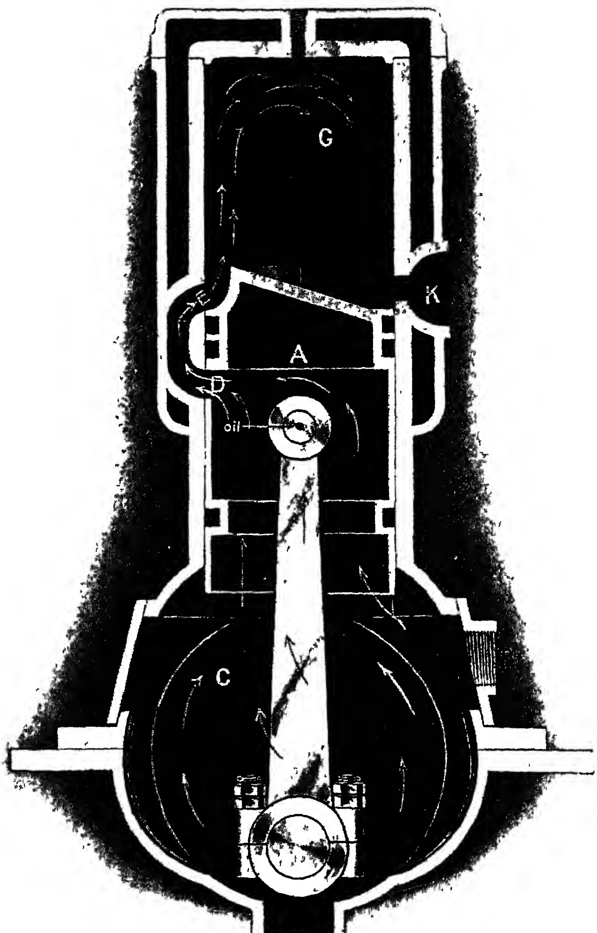


Fig. 306.—Section of small sized motor.

ward, the exhaust-port K is opened and the burned products of combustion are entirely exhausted from the cylinder, upward pressure on the valve f is thereby relieved, and the new vapor, which has been compressed in the crank-chamber by the downward

stroke of the piston, is again allowed to pass through the port D and the chamber E E E, and thus, by its pressure, forces open the valve f, which allows a new charge to enter the cylinder-chamber G.

A special feature of both types of design in the Smalley motors is the charging-port through the wall of the piston, which by its position effects a cooling influence on the piston not attainable otherwise than by water circulation, which is complicated and troublesome.

The method of oiling the piston and crank-pin is also notable in these motors. The piston-pin and connecting-rod are hollow and receive oil through the piston-pin from the cylinder oil-cup and cylinder oil-hole at the moment of exhaust.

The general agency of the Smalley Motor Company is the Fairbanks Company, corner of Broome and Elm Streets, New York.

ENGINES FOR SPEED BOATS

It is universally agreed that the jump-spark method of ignition is the best for speed boats. The "Artful," a 22-foot boat, equipped with a two-cylinder, 15-horse-power Ferro engine, took second prize in the long-distance race from New York City to Poughkeepsie, N. Y., in the summer of 1908; and a 28-foot hunting-cabin boat, 7-foot beam, with an engine of the same size and make, was first in the cruiser class, beating the rest of the fleet by forty-five minutes. This race proved that in a cruising boat the high-speed engine is capable of doing quite as good work as a slow-speed one, provided the boat is properly equipped with a suitable propeller.

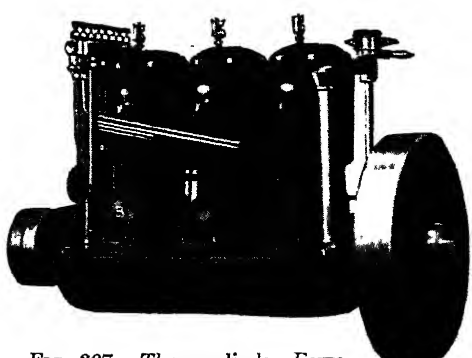


FIG. 307.—Three-cylinder Ferro engine, starboard side.

Among the improved engines of 1909, we illustrate the Ferro two-cycle three-port marine engine. This engine, manufactured

by the Ferro Machine and Foundry Company, Cleveland, Ohio, is built in three sizes, 12-, 17-, and 25-horse-power, and it has jump-spark ignition. Each cylinder is cast separately. Fig. 307 shows the general appearance of the starboard side. For a speed boat, launch, or family boat, where the minimum of vibration is desired, the three-cylinder engine is most suitable; being low and compact, it takes up very little room.

It must be remembered that, to run satisfactorily and to wear well, an engine, however well designed, and even though constructed with the best materials and workmanship, must be adequately supplied with lubricating oil. Steam-engine cylinder oil will not answer. To secure satisfactory results, a good grade of gas-engine cylinder oil *must* be used. Fig. 308 illustrates the forced feed oiling system used on this engine. The oil-tank, on the side of the base or crank-case, holds from one to two gallons of cylinder oil.

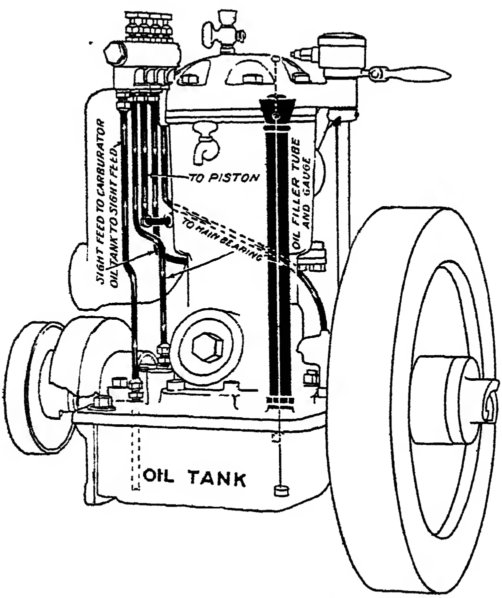


Fig. 308.—Showing oiling system.

The down-stroke of the piston, which slightly compresses the mixture in the crank-case, has a passage at the top of the oil tank connecting with the crank-case, which is controlled by a check-valve. At each revolution pressure is stored in the reservoir, and thus serves to force oil up to the sight-feed distributor through a feed tube. From the bottom of each sight-feed valve an oil-tube leads directly to each bearing and every moving part of the engine. As will be seen, the feed tube from the oil-tank, close to the bottom, conveys the oil—as shown by arrows in

the cut—up to the sight-feed distributor, the tubes leading to the main bearings and the crank-shaft being bored diagonally. The oil from the main bearing passes through the crank-shaft to the connecting-rod, the centrifugal force carrying the oil to connecting-rod bearing, thus insuring perfect lubrication. In addition, the regular "splash-feed" system, universally used by marine-engine builders, is supplied as an auxiliary safeguard against carelessness or ignorance. This consists of two wicks in the end of the connecting-rod cap, operating on the crank-shaft, which constantly feeds oil to its bearing. The oil which settles into the bottom of the crank-case forms a pool, which is thus splashed all over the interior by the rapid revolution of the crank. On the other hand, should one fail to provide oil for the splash-feed system, the pressure feed supplies oil to the crank and connecting-rod, preventing the possibility of burning out the connecting-rod bearings or cutting the crank. The tube leading to the cylinders supplies the oil direct to its inside walls at a point in line with the hollow piston-pin and oil grooves of pistons. The oil passes through the piston-pin to opposite walls of cylinders, is conveyed and distributed by grooves to all parts of the cylinder walls, is picked up by the piston-rings, and is distributed by the movement of the piston, thus thoroughly lubricating every part of the cylinder.

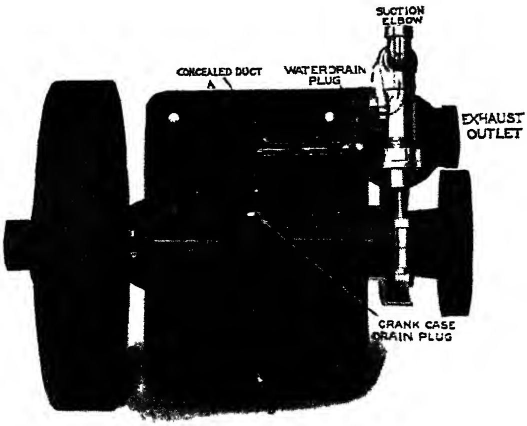


FIG. 309.—Showing water inlet, exhaust, and drainage.

The oil-filling tube contains a float showing the amount of oil in the tank, and a screw cap for filling which may be filled while the engine is running. At the top of the filler cap is a release-

valve, by turning which the pressure from the tank is relieved when the engine is not running.

The oil-tank is entirely separate from the crank-case, as shown in Fig. 309, which is a view of bottom of engine. This illustration shows how the tank is drained; also how the water is taken from the circulating pump through the case, and how this is drained. It will be seen that no piping is necessary.

COOLING THE CYLINDERS

In order to secure the best results, it is very important that the cylinders should be properly cooled. With marine engines water is used, as shown in Fig. 310. The water passes from the pump through passage in base, through the walls of the cylinder to the extreme top of cylinder-head and out through the water-cooled exhaust-jacket, which cools the exhaust-flange and helps to condense the exhaust. A portion of the circulating water is expelled direct into the exhaust condenser or silencer, passing over a deflector, further condensing the exhaust. The rest of the circulating water passes out at the top to the right, as shown by arrow in cut, and may be piped in any direction or conveyed into the exhaust-pipe beyond the condenser. When the cylinder-head is bolted to the cylinder, both are ground, and a copper-asbestos gasket is used, making leakage impossible, if only common sense be employed.

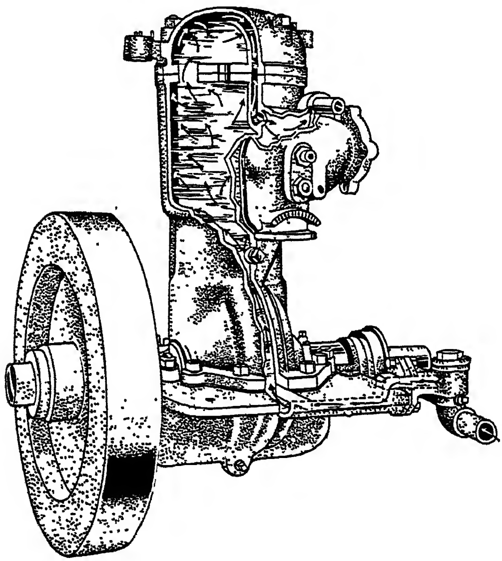


FIG. 310.—Showing water circulation.

The check-valve of pump should be examined, if a proper water supply is not obtained. If grit should cut the valve-seat, it is a

simple operation to grind it in by applying a little emery and oil on the valve-seat turning the valve.

The water intake in bottom of boat should always be provided with a screen and a scoop—the opening facing the bow, which forces the water upward to the pump.

OFFSET CYLINDER

As will be seen by Fig. 311, the cylinder is offset from the line of the center of the crank-shaft. Combustion takes place when the piston is at the top, as shown: the crank has passed over the top center, the force is applied on a working part and not on a dead center. This relieves the bearings of the constant thrust and jar, lessens the side thrust, avoids dependence upon the momentum of the fly-wheel to take it over the center, prevents kicking back, and increases the power of the engine.

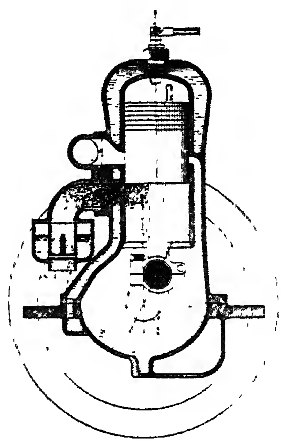


FIG. 311.—Offset cylinder.

To further illustrate the advantage of the offset cylinder, one may take the operation of a treadle, in starting which the first thing is to turn the crank over the center before applying the power—as with a bicycle foot-lathe or grindstone. No energy is wasted and no undue shock given the bearings in producing the maximum power. The offset cylinder is adopted on some of the most successful automobile motors in use to-day. (Fig. 311 also shows another view of the oil-tank, the water-intake, carbureter-intake, and exhaust.)

IGNITION AND LIGHTING OUTFIT, WITH DYNAMOS AND STORAGE BATTERY

The dynamo and storage battery for ignition and lighting, used in connection with any standard electric ignition, can be employed to supply electricity for a meter of low voltage incandescent lamps for lighting the boat. (See Fig. 312.)

The storage battery may be used singly or in a series, depending upon the capacity or duration of current required to operate a system without recharging. The dynamo furnishes the electricity to the batteries; and from them it is fed to the ignition and lighting systems. The dynamo is usually belted to the fly-wheel of the motor, but it can be used with a friction wheel or spur gear. An automatic speed governor is generally furnished with the dynamo, and serves to maintain a steady volume of current to the battery. An automatic switch breaks the dynamo circuit, when the batteries have been charged to their full capacity.

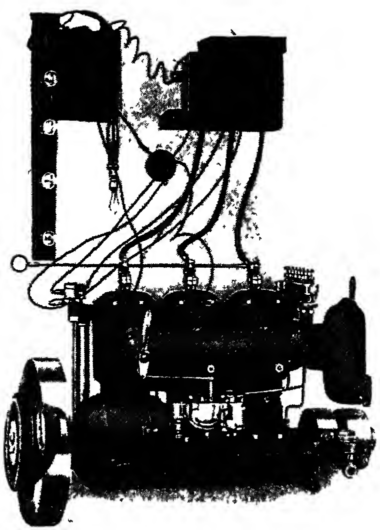


FIG. 312.—Showing lighting storage and ignition.

This system furnishes a constant and steady current, and obviates the necessity of replacement or renewals, which exists in the case of dry and wet batteries.

It is inadvisable to depend upon the dynamo alone, without any batteries, to start a motor, unless, by cranking the motor, the speed of the dynamo can be made high enough to furnish sufficient strength of electricity for ignition. Some other source of current should be used.

Fig. 313 shows a one-cylinder make-and-break. The motor is also made in two-cylinder eight, eleven, and fifteen horse-power.

MAKE-AND-BREAK IGNITION

Make-and-break or mechanical ignition is the original device used on marine gasoline engines. Although the jump-spark has largely replaced the make-and-break, still, the old method is preferable for some uses. Many mechanical devices have been employed. Fig. 314 shows the timer, which is operated with gears,

is very simple, and is not liable to get out of order. Fig. 313 shows how it is connected.

WORKING BOATS

Though more complicated than the jump-spark, the make-and-break engine is preferable for open working boats for fishermen, oystermen, and others of similar occupation.

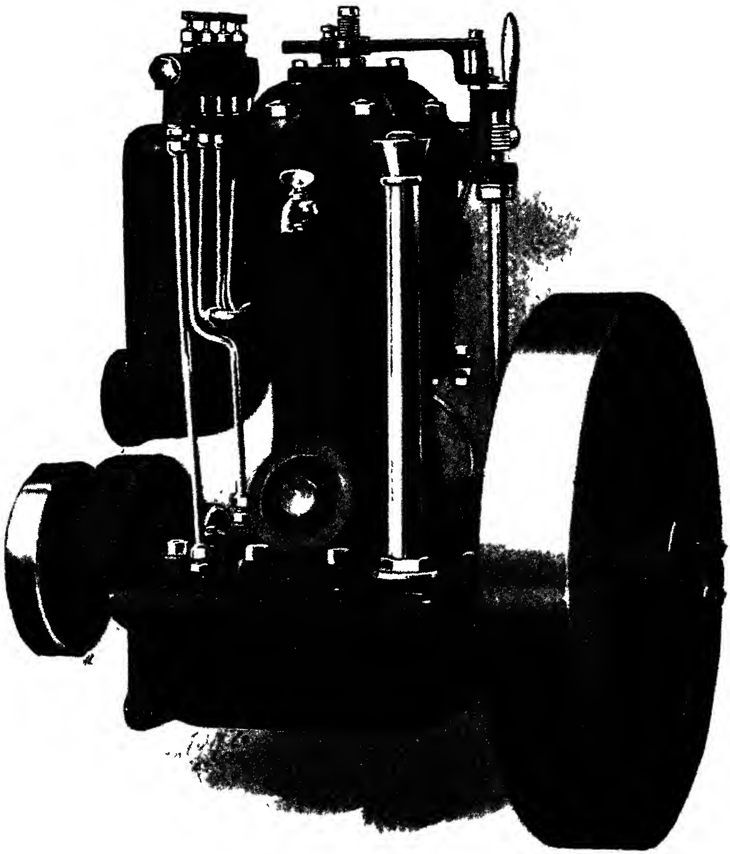


Fig. 313.—One-cylinder Ferro make-and-break motor.

In the make-and-break ignition the spark is generated in the cylinder at the same location as with the jump-spark, and is the

result of breaking an electric circuit at the points of electrodes. The mechanism consists of the sparking device, set in a brass bushing which is removable. The sparking-points are operated by the trip-rod, shown in Fig. 313, and the timing of the spark is effected by simply moving the lever (see Fig. 314), which is so constructed as to advance or retard the action of the trip-rod (shown at top of Fig. 313) and thus to give a late or an early spark.

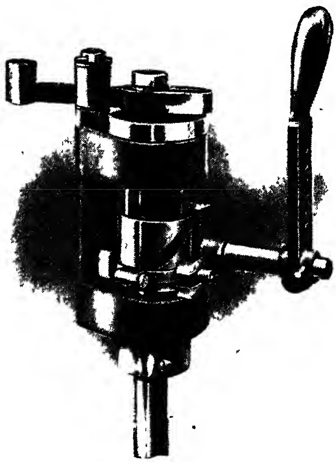


Fig. 314.—Ferro make-and-break timer.

WIRING MAKE-AND-BREAK ENGINES

Fig. 315 shows the most satisfactory method of wiring used with batteries; Fig. 316, with both batteries and dynamos. The arguments in favor of this combination hold good equally with the make-and-break system as with the jump-spark. The coil used with the make-and-break has no vibrator. It is a primary coil. The sparking-points must be kept clean and free from burnt carbon; otherwise a poor spark, or perhaps none at all, will be obtained. In order to secure the best results, one must have a good spark.

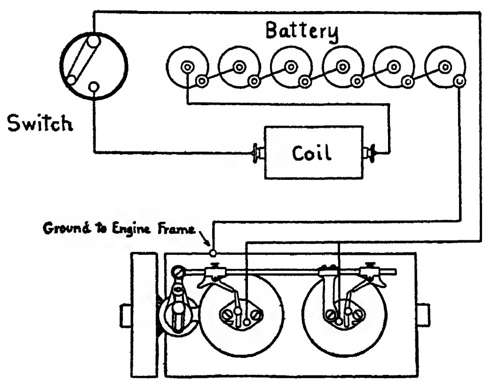


Fig. 315.—Wiring make-and-break engines.

THE FISHERMAN FOUR-CYCLE ENGINE

Fig. 317 represents a 6-horse-power four-cycle engine designed solely for fishermen, crabbers, tongers, oystermen, and ferrymen. Bore, 5″; strike, 6″; outside diameter of cylinder, $8\frac{1}{4}$″; crank-shaft,

$1\frac{5}{8}''$; propeller-shaft, 1″; diameter of fly-wheel, 20″; swings a two-blade 18″ propeller; 32″ pitch weighs about 375 pounds. Normal speed, 450 to 600 revolutions per minute; will throttle to as low a speed as 75 revolutions. Fitted with either jump-spark or make-and-break. The cylinder is offset. It is a heavy-duty engine. Manufactured by Loane-Hiltz Engine Co., Baltimore, Md.

FISHING-BOATS

Those who follow fishing for a livelihood usually need something different from other motor-boats—both as to style of boat and engine. On the Delaware and Chesapeake bays and tributaries for drift gill nets, what are known as skiffs and bateaux are used for fishing for shad, sturgeon, herring, etc. While the ordinary old-style shad skiffs are good sailers and fine sea boats, they are not capable of extra speed with motor. They will, however, make very good speed if not over-powered. These boats usually require 4 to 8 horse-power, according to size. Still, some builders have now changed the model, giving more of a speed boat, bottom and stern; and here 10 to 12 horse-power may be used. As these fishing-boats use a drift net 100 to 600 fathoms long, it is necessary in taking on the nets to be able to regulate the speed to a nicety, both in backing and in going ahead. A reversible propeller, and not a reverse gear, is the proper thing to use. A fisherman does not usually have time to slow down an engine, nor can he take any chances of the engine stopping in an attempt to slow down.

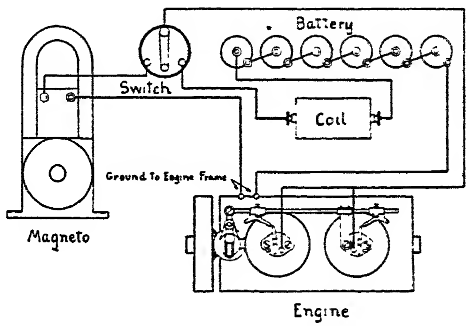


FIG. 316.—Wiring make-and-break magneto and battery.

As his boat is out in all kinds of rough weather and storms, often taking in considerable water from the net as well as from the sea, the fisherman requires a make-and-break engine in order to do away with the high-tension wire and jump-spark coil. If,

however, he uses a jump-spark engine, either the Orswell or the Perfex ignition system should be employed, which also obviates the high-tension wiring. These systems are described in the following pages.

For the surf boat, the dory, and the sea skiff, used on the

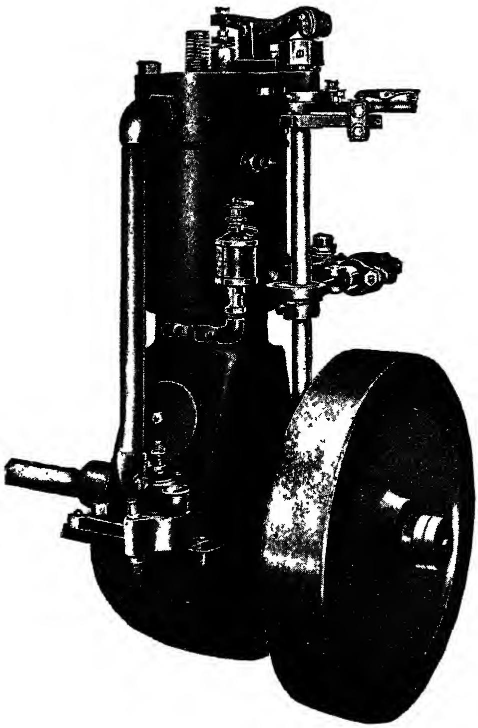


Fig. 317.—The fisherman four-cycle engine.

Atlantic Coast, on Long Island Sound, etc., either the Orswell or the Perfex ignition system or the make-and-break is largely used.

THE POWELL OPEN-BASE TWO-CYCLE ENGINE

This marine engine, manufactured by the Powell Engine Corporation, 49 Warren Street, New York City, represents a distinct type of its own, as the illustration, Fig. 318, and the sectional view, Fig. 319, show.

The piston is hollow, the charge being compressed beneath it and not in the crank-case. Compression at the bottom of the piston-chamber results in an extra-strong primary compression and quick-firing mixture at the time of explosion.

In other two-cycle engines the mixture is introduced into the base or crank-case.

It is claimed that the strong primary compression of the open-

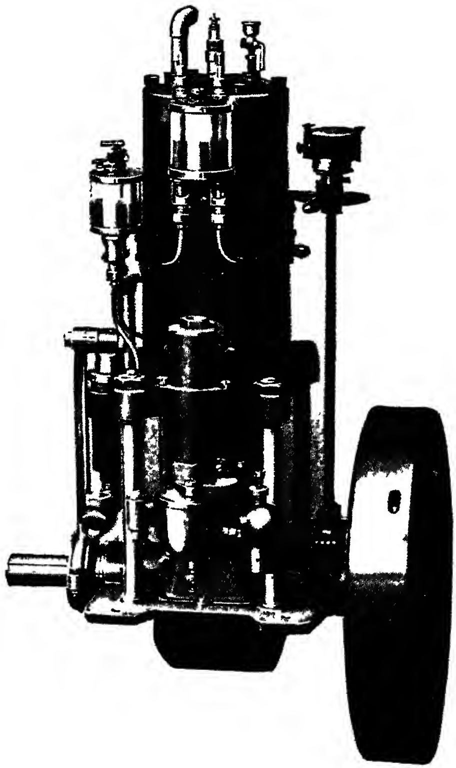


FIG. 318.—Powell open-base two-cycle engine.

base engine is more perfect in the scavenging of the cylinder, and that leakage at the crank-shaft is eliminated.

The carbureter is below the level of cylinder, preventing flooding. The advantage claimed by the open-base construction is that all parts are accessible without taking the engine apart or disturbing one cylinder to get at any part of another. The engine is

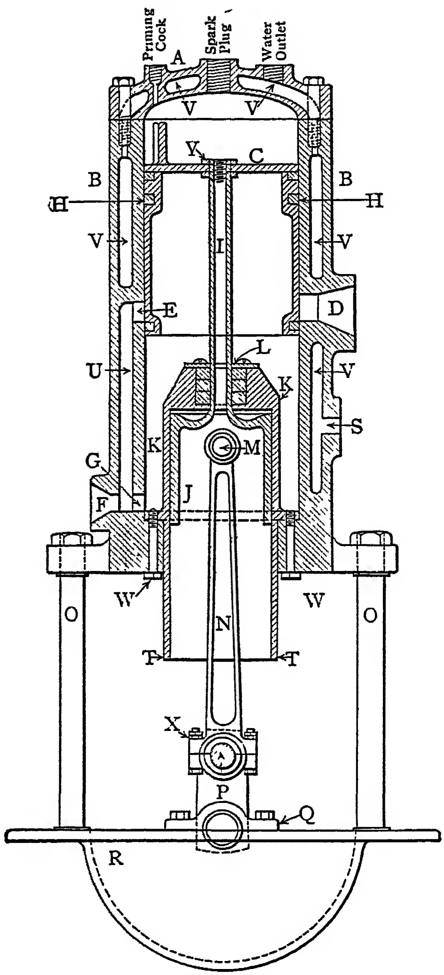


FIG. 319.—Powell open-base engine—sectional view.

A. Cylinder-head.
B. Cylinder.
C. Piston.
D. Exhaust port.
E. Intake port.
F. Intake passage.
G. Intake passage to compression-chamber.
H. Piston-rings.
I. Piston-rod. } Note piston-rod and cross-
J Crosshead. } head are one steel casting.
K. Compression-plate.
L. Piston-rod packing-rings.
M. Wrist-pin.
N. Connecting-rod.
O. Stanchion.
P. Crank and crank-pin.
Q. Crank-bearing cap.
R. Foundation frame.
S. Water-inlet.
T. Guides for crosshead.
U. Transfer passage.
V. Water-jacket.
W. Bolts which secure compression-plate and crosshead to cylinder.
X. Connecting-rod bolts.
Y. Lock-nuts which secure piston to piston-rod.

fitted with oil-guards which surround the crank-arms and are easily removed, and prevent oil from being thrown about the boat.

Bearings are reversible, interchangeable, and renewable. The engines are manufactured in one, two, three, and four cylinders, of 5 horse-power each, and are designed to run at 525 and 500 revolutions. The sectional view, Fig. 319, gives a list of parts showing the construction.

GLOBE MARINE ENGINE

This engine (Fig. 320) is of the internal-combustion type, using gasoline, varying in specific gravity from 64 to 88 degrees.

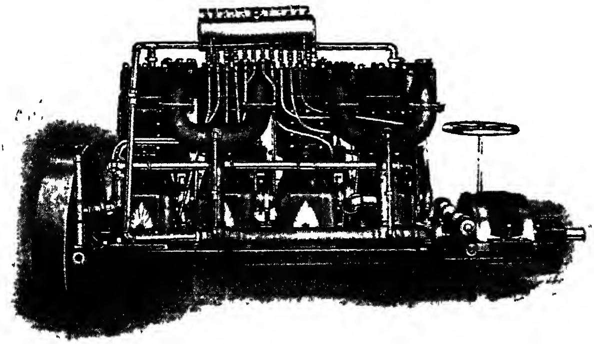


Fig. 320.—Globe engine.
Forty horse-power, four-cycle, four-cylinder, type S, heavy duty, rear view. Manufactured by Pennsylvania Iron Works, Eddystone, Pa.

The theory of operation of the four-cycle or four-stroke principle is an explosion taking place in each cylinder at every other revolution.

On the first down-stroke of the piston, a charge of explosive mixture is drawn into the cylinder. During the first up-stroke of the piston (the second stroke), the charge is compressed and exploded by means of an electric spark, when the piston is approximately at the top center of its travel; and the increased pressure exerted thereon, due to the sudden expansion of the heated gases, drives the piston forward on the second downward or, commonly called, power stroke (third stroke). The second up-stroke (fourth

stroke) expels the burnt gases, leaving the cylinder clean and ready for the next charge, thereby completing the cycle of the engine—four strokes, or four cycles. The four-cycle principle is considered by most authorities to be the most economical for heavy-duty, slow-speed engines.

The Globe engine consumes fuel in proportion to the power used. Under actual working conditions, when running at maxi-

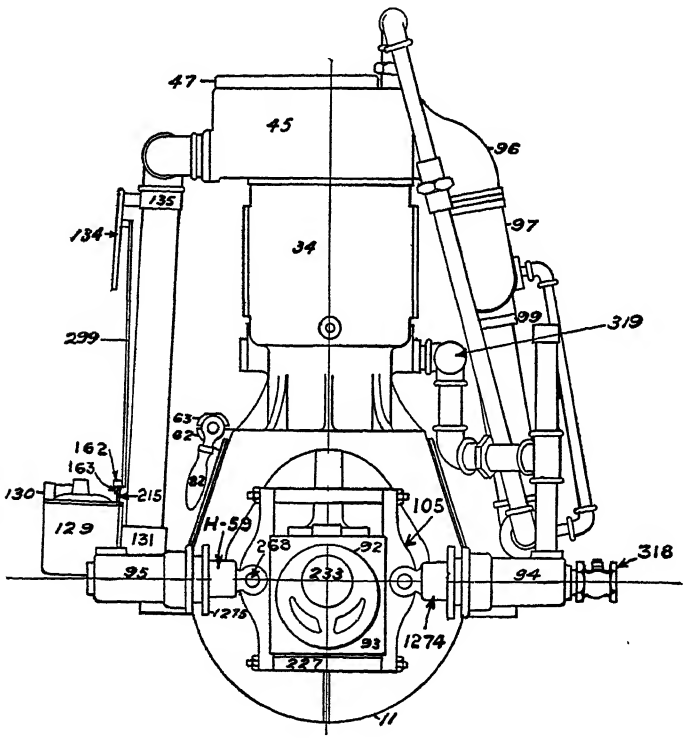


FIG. 321.—Globe engine—forward end view, showing pump operated by eccentric.

mum speed and power, the smaller size consumes one-sixth of a gallon per horse-power; the larger size, one-eighth to one-tenth gallon per hour.

This engine is built in 20-, 30-, and 40-horse-power sizes. The frame and cylinder are cast in one piece for each cylinder unit, and are mounted separately on the bed-plate of the engine.

The operation of each igniter and exhaust-valve is independent of the other, being actuated by a separate set of gears for each cylinder unit.

A single hand-lever regulates simultaneously for all cylinders. The spark advances in connection with the action of the relief-cam when starting the engine. The cylinder bore is 7½ inches; stroke,

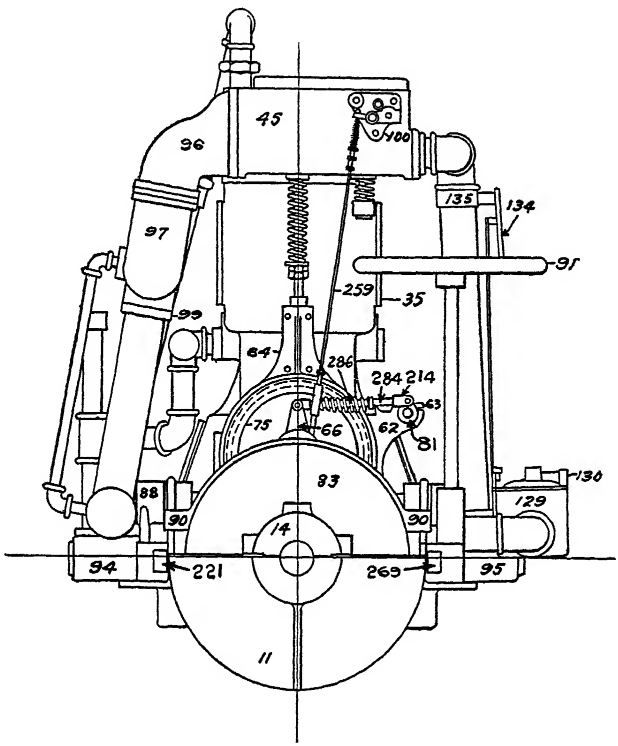


FIG. 322.—Globe engine—aft view, showing piping system.

9 inches; 20 horse-power designed to run 350 revolutions per minute; 30 horse-power, 335 revolutions per minute; 40 horse-power, 325 revolutions per minute.

The illustrations show the valve mechanism, as well as piping, forward and aft views. The numbers and terms refer to corresponding numbers on the cuts, and will enable the novice to understand thoroughly the construction and working of the Globe engine.

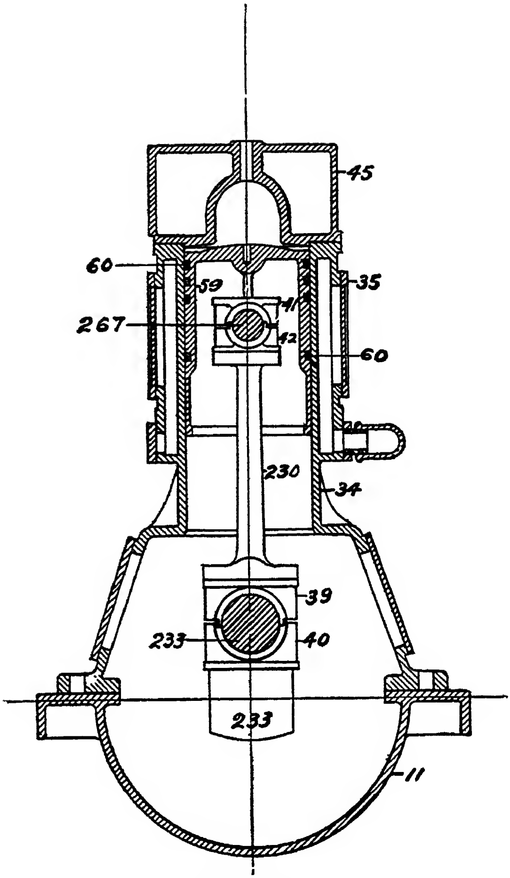


FIG. 323.—Globe engine—sectional view.

11—Bed-plate.
12—Main-bearing cap for'd.
13—Main-bearing cap.
14—Thrust-bearing cap.
34—Cylinder.
35—Cylinder name-plate.
39—Connecting-rod box C. E. T.
40—Connecting-rod box C. E. B.
41—Connecting-rod box P E. T.
42—Connecting-rod box P. E. B.
45—Cylinder-head.
46—Air-pipe flange.
47—Valve-chest cover.
48—Exhaust-valve bushing.
49—Inlet-valve bushing.
59—Piston.
H-59—Air-pump plunger.
60—Piston-rings.
62—Valve-gear bracket.
63—Valve-gear-bracket cap
64—Splash-guard.
66—Shifting-arm.
75—Exhaust-gear.
76—Fly-wheel.
77—Aft-exhaust-gear. pinion.
81—Shifting collar.
82—Relief-handle.
83—Clutch-drum.
84—Clutch-spider.
85—Clutch.
86—Clutch-dogs.
87—Spreader levers.
88—Rack levers.
89—Spreader finger.
90—Brake-band.
91—Hand-wheel.
92—Eccentric body.
93—Crosshead.
94—Water-pump body.
95—Air-pump body.

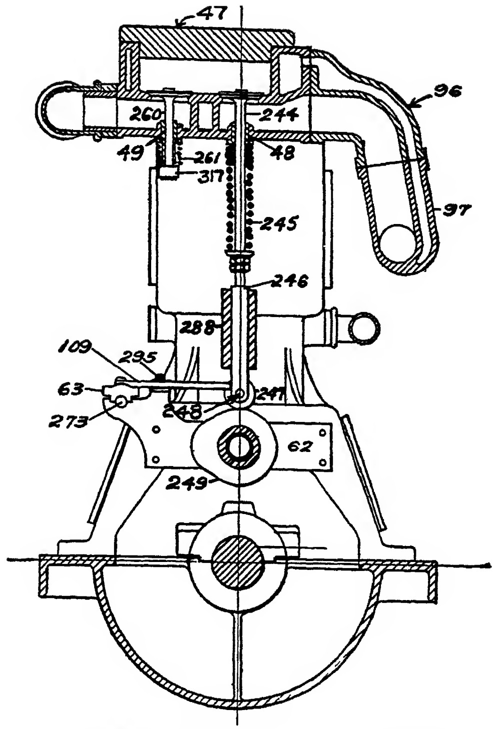


FIG. 324.—Globe engine—valve mechanism.

96—Exhaust-ell.
97—Exhaust-chamber.
99—Exhaust-pipe flange.
100—Electrode bearing.
102—Rack-block.
103—Pinion-block.
104—Pinion-block cover.
105—Crosshead guide.
106—Bushing for short rev. pinion.
107—Bushing for long rev. pinion.
109—Relief-cam lever
134—Throttle-lever.
135—Throttle-lever bracket.
218—Horizontal check.
221—Rack.
227—Crosshead guide-bolt.
230—Connecting-rod.
233—Crank-shaft.
234—Clutch-dog adjusting bolt.
235—Clutch-dog bolt.
236—Clutch-shaft.
244—Exhaust-valve.
245—Exhaust-valve spring.
246—Exhaust-valve slide-bar.
247—Exhaust-valve slide-bar roller.
248—Exhaust-valve bar-pin.
249—Exhaust-cam.
250—Exhaust-gear pinion.
257—Hand-wheel shaft.
258—Hand-wheel coupling.
259—Igniter-rod.
260—Inlet-valve.
261—Inlet-valve spring.
267—Piston-pin.
269—Pinion-rack
270—Rack-bolt.
271—Rack-band clamp screw.
273—Relief-shaft
277—Short reverse-pinion.
278—Long reverse-pinion.
279—Long reverse-pinion pin.
280—Short reverse-pinion pin
281—Propeller-shaft rev. gear
282—Crank-shaft rev. gear.
283—Reverse cross-shaft.
284—Shifting-rod.
286—Shifting-rod spring.
288—Slide-bar guide.
289—Spreader.
298—Thrust shaft.
299—Throttle rod.
317—Inlet-valve collar.
319—Angle-check.
295—Relief-cam lever-stud.
268—Pump plunger-pin.
320—Clutch set-screw.
321—Clutch shaft-bolt.
1274—Water-pump plunger.
1275—Pump-glands.

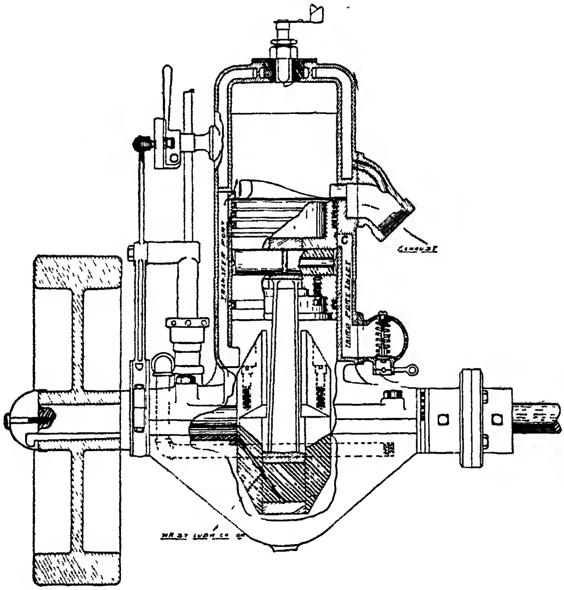


FIG. 325.—Grasser marine engine—sectional view.

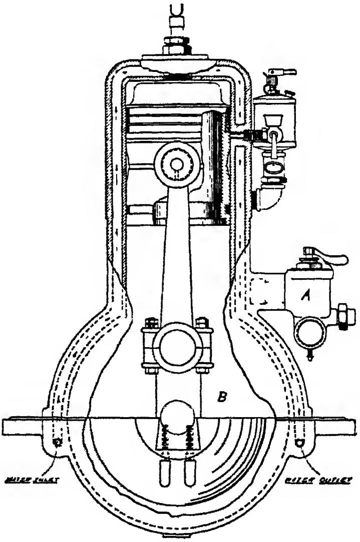


FIG. 326.—Grasser marine engine—sectional view.

GRASSER MARINE ENGINE—COMBINATION TWO-PORT, THREE-PORT

In this engine, manufactured by the Grasser Motor Co., Toledo, Ohio, the most important and distinct feature is the combination. It is claimed that it has all the advantages of both, without any of the disadvantages. The difference between the combination two-three port and the ordinary two-cycle will be readily seen, if reference be made to the sectional illustrations, Fig. 325 and Fig. 326.

As the piston starts on its up-stroke, the charge is drawn through the generator valve A into the crank-case B, until the third port C is opened, allowing the remaining vacuum to be displaced by air through the third port C, which would not otherwise be displaced. When the piston starts on its down-stroke, valve A closes; the result is a full charge in crank-case, which means a larger charge in the cylinder, more power, and an absence of crank-case firing.

The ports are placed in the forward and aft sides of the cylinder. The reason for this is that the thrust of the piston is always sideways; and, by maintaining a solid wall on the sides without ports, the wear will be longer than when there is no thrust fore and aft on the piston. This style of engine is made in 3, 6, 10, and 15 horsepower. On the starboard side of the engine a generator is connected direct to the crank-case, using a check-valve as in a two-part engine, forming the two-port system; another generator on the port side of the cylinder supplies gas through the third port. An improved generator-valve with throttle control is used. Each cylinder has its own generator.

The water circulation as well as the general construction is shown in the two illustrations.

SCRIPPS LIGHT-WEIGHT FOUR-CYCLE ENGINE

Scripps motors, manufactured by Scripps Motor Co., Detroit, Mich., are of the four-cycle type, having both inlet- and exhaust-valves on the same side of cylinder and operated by the same camshaft (Figs. 327 and 328). They are provided with roomy handholes on side of crank-case, giving free access to connecting-rods and main bearings.

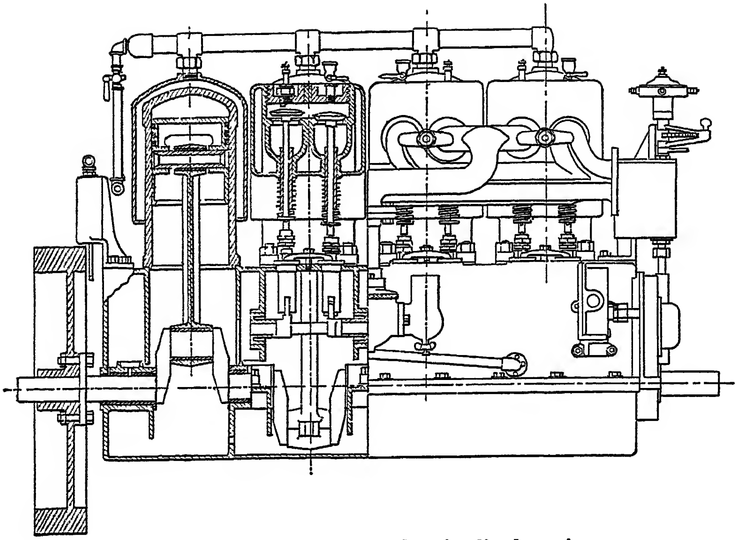


FIG. 327.—Scripps motor—longitudinal section.

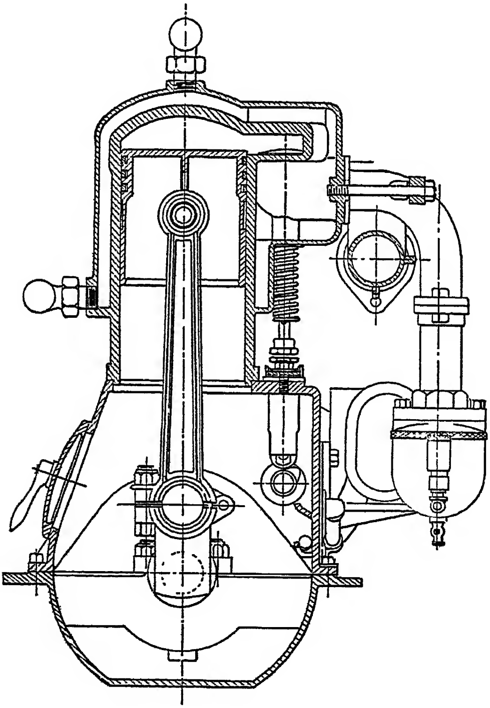


FIG. 328.—Scripps motor—lateral section view.

The main bearings are supported by webs or partitions which divide the lower half of crank-case into separate compartments for each cylinder. Thus the two-cylinder size has three bearings, the four-cylinder has five, and the six-cylinder, seven. They are lined with the highest grade of babbitt obtainable and are scraped to a perfect bearing. The same applies to connecting-rod bearings. All gears are encased, and by the use of a bronze intermediate gear are rendered practically noiseless. Control levers are located at a convenient point, so that the operator may easily reach them while sitting in a position to reach the reverse lever.

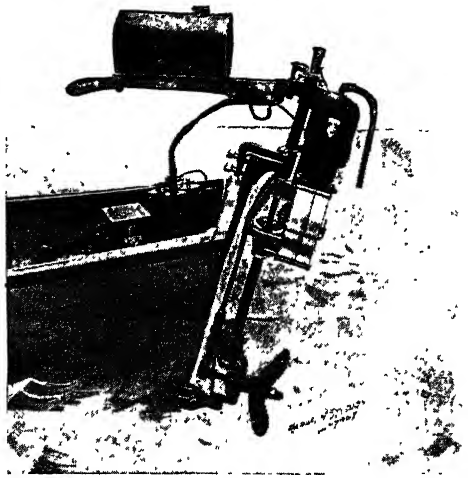


Fig. 329.—Waterman outboard engine—ready to operate.

In order to meet the demand for a purely high-speed racing machine of high power, Scripps Motor Co. are now building a six-cylinder motor $6\frac{1}{4} \times 6$, rated 100 horse-power, normal speed 1,000 revolutions per minute. The general dimensions are the same as the six-cylinder $5\frac{1}{2} \times 6$, and the weight approximately 1,025 pounds. The clutch supplied with this motor is of special design, with aluminum case, and weighs less than 100 pounds. The crank-shaft is made of chrome-nickel steel, the highest grade of steel obtainable.

Figs. 327 and 328 show longitudinal and lateral sections.

WATERMAN OUTBOARD ENGINE, FOR CANOES, TENDERS, ROW-BOATS, ETC.

This engine, manufactured by the Waterman Marine Motor Co., Detroit, Mich., can be shipped like a rudder, and actually takes the place of a rudder, besides driving the boat. Fig. 329 shows it

attached ready for use, the gasoline tank on the tiller. The ignition equipment may be placed in any part of the boat—usually it is on the stern. Fig. 330, sectional view, illustrates how to attach it, and the construction.

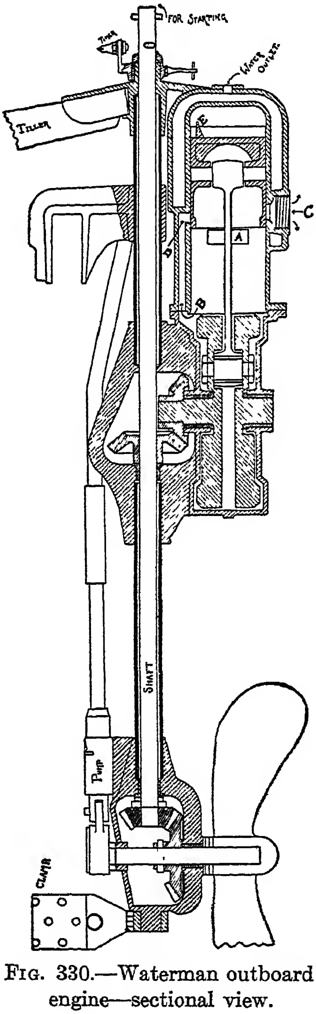


FIG. 330.—Waterman outboard engine—sectional view.

This engine may be quickly attached to or detached from any row-boat, and fills a distinct want. It will enable one to convert a row-boat into a motor-boat in a very short space of time.

PROPELLERS—HOW TO TELL A RIGHT-HAND FROM A LEFT-HAND PROPELLER

Right- or Left-hand Engine, Fig. 332.—In facing the fly-wheel looking aft, if top of fly-wheel turns from the right to the left, a right-hand propeller is required; if top of fly-wheel turns from the left to the right, a left-hand propeller.

Right or Left Propeller, Fig. 331.—In standing aft of the stern of boat, facing the bow, a right-hand propeller enters the water, turning to the right, just as a right-hand screw. A left-hand propeller enters the water, turning to the left, similarly to a left-hand screw, both taking the water on the back or flat side of the blades. The crowning side of the propeller should be next to the boat, the flat side or working surface aft.

PROPELLERS

The manufacturers of engines usually supply a wheel of the best size and style to suit a particular engine, in order to give the best

results, as it requires a propeller of a certain size and pitch to give the desired number of revolutions to develop the horse-power of the engine; and the user will do well to take their regular equipment, and then, if not satisfied with results, experiment for his own gratification. It should be remembered that when the size and pitch of propeller are increased the speed of engine is decreased and the horse-power is reduced.

The propeller should always be entirely submerged; the deeper it is in the water, the greater the hold it will take on the water. For

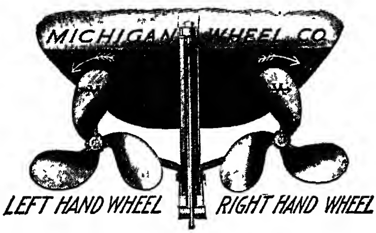


FIG. 331.—Right-hand and left-hand propeller wheels.

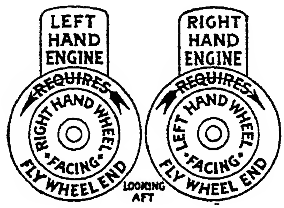


FIG. 332.—Right and left engines.

high-speed or very high-speed engines the universal opinion is that a two-blade propeller gives the best results for engines below 15 horse-power. The novice who has his own ideas about propelling and propellers should remember, if a propeller screws through the water eight miles per hour and there is no slip (but there is), it would be necessary to increase the speed of the propeller or use a greater pitch or a larger wheel to get more speed out of the boat. This cannot be done with the same power, of course admitting that, according to design and build of the boat, some styles, sizes and pitches will give better results; this is purely a question of experimenting, and a novice will be more apt to get best first results by the manufacturer's selection than by his own.

In ordering an engine outfit or a propeller, always state the probable size of the boat, giving style of boat, length, beam, and draught, and whether heavy or light build.

THE TWENTIETH CENTURY SPEED PROPELLER

This propeller, manufactured by Michigan Wheel Co., Grand Rapids, Mich., is designed for speed. It takes the water at the

shaft, and gives a continuous push to the extreme end of each blade. It may be used on all kinds of boats for racing and pleasure, particularly on light boats; and its design is such that it will pass over logs, rocks, etc., with less liability to break or bend than the ordinary propeller, and through weeds without liability to foul, as

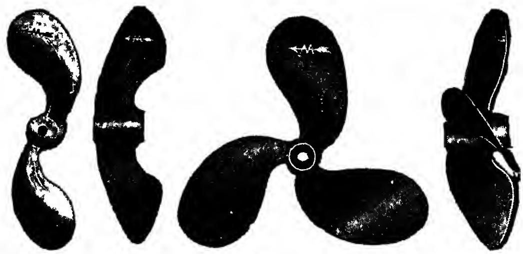


FIG. 333.—Twentieth Century speed wheel—semi-weedless.

it is almost a weedless propeller. The width of the blades is one-fourth the diameter of the propeller. The following table gives the diameter, pitch, and horse-power per 100 and 400 revolutions.

Two-Blade				Three-Blade			
Diameter. Inches.	Pitch.	Horse-power. 100 Rev.	Horse-power 400 Rev.	Diameter Inches.	Pitch.	Horse-power 100 Rev	Horse-power. 400 Rev.
10	14	.3	1.25	12	16 8	8	3
11	15	4	1 50	14	19 6	1	4
12	16	.5	2	16	22 4	1 75	7
13	18	.6	2 40	18	25.2	2 5	10
14	19	75	3	20	28.0	4	16
16	22	1 25	5	22	30 8	5	20
18	25	2.	8	24	33 6	7	28
20	28	3	12	26	36 4	9	36
22	30	4	16	28	39 2	10.	40
24	33	6.	24	30	42 0	12.	48
				33	46.2	14.	56
				36	50.4	16.	64
				40	56.0	18.	75
				44	61.6	22.	90
				48	67.2	24.	100

In calculating the size of propeller required, if not shown in the tables, it will be seen that a 1-horse-power engine at 100 revolutions requires a 16-inch diameter (see Towing Propellers) propeller, with 17.6-inch pitch. A 4-horse-power at 400 revolutions re-

quires the same propeller. An 8-horse-power engine at 800 revolutions would require a propeller of about the same size as a 1-horse-power at 100 revolutions.

The pitch of a propeller is the distance it would advance at one revolution if turning in solid material, as a screw in metal.

SELECTING PROPELLERS

If an engine is designed for and does develop a certain horse-power at 350 revolutions, and the propeller is not properly selected, so that the engine will turn up only 250 revolutions, then the engine is not developing the rated horse-power; in order to develop its full power such a diameter and pitch as will turn 350 revolutions should be used. If designed to run 700 revolutions and it turns up only 500, the propeller is not suited for the engine, as above. Either the slow- or high-speed engine may be run at a slower speed if desired with less power.

On the other hand, if your engine is designed to run at 700 revolutions and it turns up 1,000 revolutions, better results would be obtained, with most boats, if a propeller with greater pitch to bring it down to 700 or 800 revolutions were used. Should the boat be a heavy, wide-beam one, a larger propeller with less pitch is preferable to a smaller one with greater pitch, and usually a two-blade propeller will give better results with most boats, particularly when there is a wide dead-wood or for auxiliary use.

For speed boats under 15 horse-power, the two-blade is undoubtedly the best.

More solid water is obtained with two blades than with three.

THE MICHIGAN WEEDLESS SPEED PROPELLER WHEEL

This is a perfectly weedless speed propeller. In operation, it rotates the forward edge of the blades through the water in a curve at an acute angle to that edge, thus cutting the water with a sliding motion. Any weeds, grass, or other obstruction engaged thereby will slide along the forward edge toward the periphery, and be discharged from the outer edge of the blades. The propeller is thus made self-cleaning and will not become fouled.

This propeller is greatly appreciated by hunters among the

marshes and weeds, making motor-boating a pleasure in lakes, rivers, and bays, where weeds would otherwise be troublesome.

It is easily attached to any propeller shaft, and should be placed close to the stern bearing, a weedless rudder, shown in Fig.

FIG. 334.—The Michigan weedless speed propeller wheel.

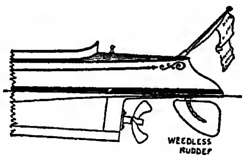


FIG. 335.—Showing weedless rudder.

335, being fixed as far back of the propeller as possible. Set-screws, if used on the propeller, should be flush with the outside of the hub.

MICHIGAN WEEDLESS TWO-BLADE PROPELLER

Diameter. Inches.	Pitch. Inches.	Horse-power 100 Revs	Horse-power. 400 Revs.
10	14	20	75
11	15	25	1
12	16	40	1 50
13	17	45	1 75
14	19	60	2.
16	22	1 00	4
18	25	1 50	6
20	28	2 25	9
22	30	3	12.
24	33	4	16.
26	36	6.	24.

PROPELLERS FOR HEAVY BOATS

It often happens that, with a heavy boat, or extreme beam, or deep draught, when the propeller is deeply submerged, the propeller

usually sent out by the manufacturers with the ordinary outfits does not give the best results, and the engine fails to run near the number of revolutions intended in the average light boat. In this case the pitch of the propeller should be reduced or a propeller with about 3 inches less pitch should be substituted.

For instance, if employing a 15-horse-power engine with propeller 20 inches in diameter and 27-inch pitch, with above results, use in its place a 20-inch propeller with 24-inch pitch. Remember this is a suggestion to work by, and not a set rule. Some boats may require still less pitch. It depends upon how fast the engine runs with the 27-inch pitch, etc.

The table on page 362 will show the approximate requirements for the average pleasure boat.

Taking into consideration the speed your engine is intended to run to develop its rated horse-power, by ascertaining the revolutions the propeller is making, it can be readily determined whether one of more or less pitch, or of greater or less diameter is needed.

MICHIGAN TOWING PROPELLERS

The "Michigan" is specially designed as a towing propeller on the true screw pitch (see Fig. 336), allowance being made for slip-

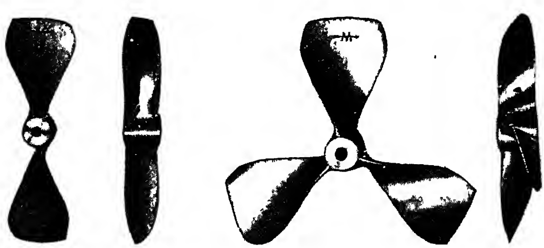


FIG. 336.—Michigan towing propeller wheels.

page at the hub. It is adapted for heavy boats with powerful engines requiring a large blade area. The width of the blade is one-third its diameter. A portion of the back of the blade is flat, to give power in backing. This propeller may also be employed to advantage with high-speed engines, with a heavy, deep-draught, extreme beam, requiring a larger diameter than that of the speed

propeller. The following table gives diameter, pitch, and horse-power for propellers of two and three blades:

Two-Blade Towing Propeller				Three-Blade Towing Propeller			
Diameter Inches.	Pitch Inches.	Horse-power. 100 Revs	Horse-power 400 Revs.	Diameter Inches.	Pitch Inches.	Horse-power 100 Revs.	Horse-power 400 Revs
16	17 6	1	4	16	17 6	1 50	5
18	19.8	1 5	6	18	19 8	2 25	9
20	22 0	2 25	9	20	22 0	3	12
22	24 2	3	12	22	24 2	4	16
24	26 4	4	16	24	26 4	6	24
26	28 6	6	24	26	28 6	7 5	30
28	30 8	7 5	30	28	30 8	9	36
30	32 3	9	36	30	32 3	10	40
				33	36 3	12	48
				36	39 3	15.	60

Should a propeller be found too large to enable the engine to turn up the required number of revolutions, trim off the outer edges a little at a time. Care should be used to take the same amount off of each blade.

IMPROVED MOTOR-BOAT FITTING

One of the most important things to consider is the installation of the engine. Many engines are not properly lined up; and even when the engine is perfectly lined, so that the propeller-shaft coupling and engine coupling fit properly, with no bind on the stuffing-box when the boat is out of the water, frequently after launching the boat takes a different set, causing the shaft to bind in the ordinary stuffing-box. This often causes difficulty and sometimes complete failure in starting the engine. Expansion from moisture, or shrinkage in the engine-bed, even after the engine has been reset, causes trouble after launching. The Glens Falls Manufacturing Company, Glens Falls, N. Y., have entirely overcome these difficulties by introducing ball-bearing devices, as shown in Figs. 337 and 338.

BALL-BEARING STUFFING-BOX

The ball-bearing stuffing-box, Fig. 337, for the shaft log or dead-wood, as the case may be, is available either inside or outside

of the boat. The sectional view shows how the shaft is always in line with the crank-shaft of the engine. In Fig. 338, S shows the shaft running through the stuffing-box. When the shaft is coupled

FIG. 337.—Ball-bearing stuffing-box.

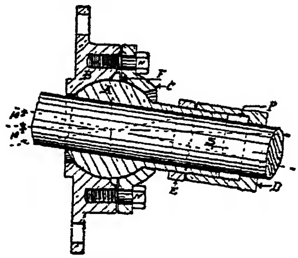


FIG. 338.—Ball-bearing stuffing-box—sectional view.

to the engine, the cap nuts should be set tightly enough to hold the packing around the ball from leaking. This will allow the ball-bearing to adjust itself to the proper shaft-line after the boat is afloat.

FIG. 339.—Speed boat stuffing-box (ball-bearing), for inside or outside.

Fig. 339 shows stuffing-box made for speed boats, to be used inside or outside, or when long shafting is employed, and an inside and an outside bearing are needed, forming an intermediate bearing on the propeller shaft. If desired, an intermediate bearing may be used, and the stuffing-box cap dispensed with.

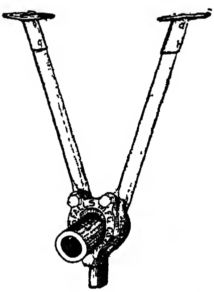


FIG. 340.—Ball-bearing shaft-hanger.

BALL-BEARING SHAFT-HANGER

The shaft-hanger, or shunt, Fig. 340, is for speed boats; and the hangers are made in different lengths, and are bolted to the bearing, being cut to length desired, and bolted to the bottom. The bearing is the same as that used in the stuffing-box, but without packing-box. This is not only a convenience, but it insures proper alignment.

FLEXIBLE SHAFT COUPLING

This flexible shaft coupling (Fig. 341) is superior to the ordinary universal-joint, for the reason that it will operate in the transmission of power shafts, both on an angle and also when the

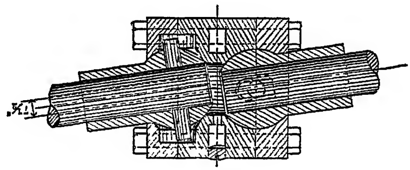


Fig. 341.—Flexible shaft coupling.

two shaft ends are out of alignment; whereas, a universal-joint necessitates the absolute adjustment of the two shaft ends upon the center of the knuckle.

By means of this flexible coupling, the installation of an engine in a boat becomes a simple operation. The engine can be placed in a horizontal position, or nearly so, with two flexible pipe fittings (Figs. 342 and 343) on ball-bearing, and any irregular or regular

Fig. 342.—A flexible elbow union.

Fig. 343.—A flexible union.

angle may be made; also vibration, crooked threads, etc., are provided for, and the annoyance of bending pipe is obviated. They also allow for expansion and contraction, and thus are preventative of leaky joints.

SUBMERGED EXHAUST

This exhaust outlet (Fig. 344) is placed in the bottom or the side of the boat below the water line, as far forward of the propeller as possible, and five or more inches under water. Captain

Walters, the inventor of these devices, is one of the pioneer designers of motor-boats. Several departments of the United States Government are now using these devices with success.

STRAINING GASOLINE

While it is always assumed that operators of gasoline engines will strain the gasoline when filling the tank, still, as a precaution, a strainer fixed in a convenient place between the tank and carbureter is desirable and will save trouble.

Fig. 345 shows a very handy appliance of this kind, namely, the Racso Twin Gasoline Strainer, manufactured by Oscar Schoge, 556 Evergreen Avenue, Brooklyn, N. Y. It has two strainers, and the advantage is that should one strainer

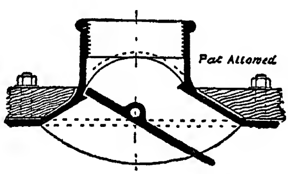


FIG. 344.—Submerged exhaust —for racing boats.

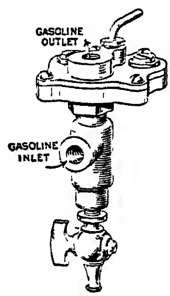


FIG. 345.—Gasoline strainer.

get clogged with small particles of paraffin, glue-particles from tank or piping, etc., instead of shutting off the engine to clear strainer, all that is necessary is to push the handle or lever, which removes the clogged strainer, and a clean one can be fixed in its place without interruption. The clogged strainer may be cleaned at leisure and held ready for future use. It is very little trouble to install one of these strainers, and its adoption may save much inconvenience and annoyance.

SURF FISHING AND WORKING BOATS

When the jump-spark engine is adopted in open boats for above use, it is advisable to provide a protection to the spark-plug, or, still better, to use one of the ignition systems described below.

The spark-plug and induction-coil are combined, the coil being

encased in heavy mica, hermetically sealed. Outside this is a brass casing that protects and supports the whole.

There is no ground connection of the secondary terminals, as these are connected inside directly to the sparking-points, making a double-pointed plug. It can be readily seen that from this con-

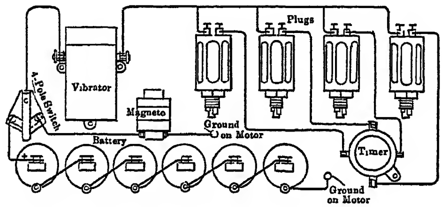


FIG. 346.—Wiring with magneto—Orswell system.

struction there is no high tension or secondary current except at the sparking-points, and no leakage of current from moisture or water, or short circuits from any causes, as all wires and connections that are exposed carry the primary or low volt current only.

The secondary current or jump-spark produced by this system

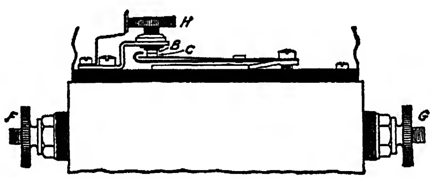


FIG. 347.—Adjustment of vibrator—Orswell system.

Armature (*A*) should be in contact with platinum spring (*B*) but not pressing upon it. To determine this, press down spring (*B*). If armature (*A*) does not follow spring, it is in right position. If it follows, bend slightly upward.

The platinum spring (*B*) should have a moderate tension, sufficient only to give it moderate contact with the platinum bracket (*C*). This is adjusted by turning the screw (*D*) in the end of the brass rocker (*E*).

Change connecting wires at (*F*) and (*G*) once or twice a week—wire (*G*) to (*F*) and wire (*F*) to (*G*), to even up wear of the platinum points.

If vibrator should fail to start at any time, the platinum points should be cleared of any foreign matter which may have lodged between them.

With proper adjustments, excessive current consumption is avoided. Any system, when not well adjusted, will consume current quickly.

Manufactured by Orswell Igniter Co., 190 Commercial Street, Boston, Mass.

is 100 per cent. greater than is necessary to penetrate the highest compression allowable in explosive motors.

It is of very high frequency which makes a quality of spark that will explode any mixture that is ignitable.

The spark-plug and vibrator constitute a complete jump-spark system, to be used together, one vibrator only, instantly adjusted, being necessary for any number of cylinders.

If the motor was made to use the ordinary jump-spark, it will require no change to use this system. If it is a make-and-break, it will require some kind of timing device to complete the circuit at the desired time.

This system is suitable for marine, automobile, or stationary motors.

WIRING WITH BATTERIES

The Perfex igniter (Fig. 348) combines the waterproof advantages of the make-and-break system, the single-vibrator feature of the distributor system, the cheapness of the common jump-spark system, and in addition does away with the bulky coil-box and

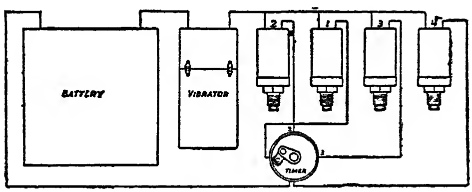


FIG. 348.—Perfex igniter—wiring with batteries.

the high-tension wires. Contact-points and spark-points are renewable without taking vibrator or igniter apart.

Only one vibrator is required for any number of cylinders.

Primary wiring only is required; this diagram shows its simplicity. Cut off the three right-hand igniters and the remainder will show method for single cylinder.

The timer, or wire leading to it, should be grounded in the engine.

The binding posts of igniter are its two primary terminals; the spark-points are its two secondary terminals; so each igniter completes its circuit within itself when, and only when, the timer makes contact for that circuit.

Current may be used from dry cells, storage-battery, dynamo or any magneto that will operate jump-spark. The battery consumption is about equal to the average economical coil, and less than many of them.

It will operate on three or four cells, but to use six is more economical. The condenser is made for use of about eight volts. Much more or less voltage than this is not desirable.

APLCO DYNAMO

This dynamo (Fig. 349), made by Apple Electric Co., Dayton, Ohio, has both bearing-heads and brush-holders cast in one piece.

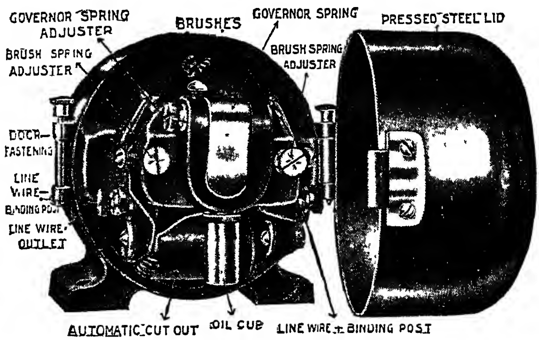


FIG. 349.—"Aplco" ignition dynamo.

The brushes are self-lubricating, dust- and water-proof, can be driven in either direction, belt, friction, or gear driven.

Fig. 350 is a sectional view showing the governor mechanism. The action of the governor is to oscillate the dynamo armature, to

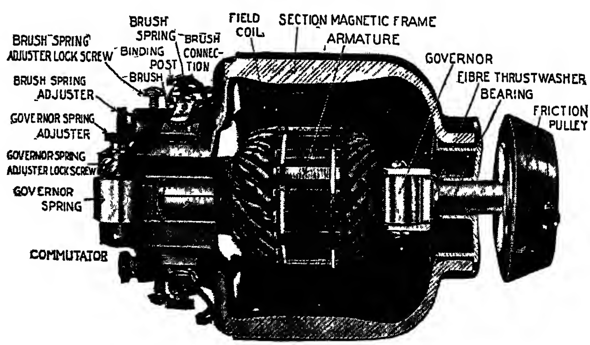


FIG. 350.—"Aplco" dynamo—sectional view.

which is attached the friction pulley. This distributes the oil in the bearings, and prevents the brushes from tracking, thus increas-

ing the life of the wearing parts. An automatic cut-out is located within the dynamo. It makes connection with the storage-battery the instant the dynamo voltage reaches a certain value, thus charging the storage-battery. It severs the connection between the dynamo and the battery the instant the dynamo drops below a certain speed or stops, thus preventing the discharge of the storage-battery back through the dynamo. The latter, if not prevented, would injure the dynamo and exhaust the battery. The armature, even if pushed in with the finger, will not stay in and discharge the battery when the dynamo is not running. Thus the cut-out automatically switches the dynamo circuit on and off the storage-battery circuit at the proper time.

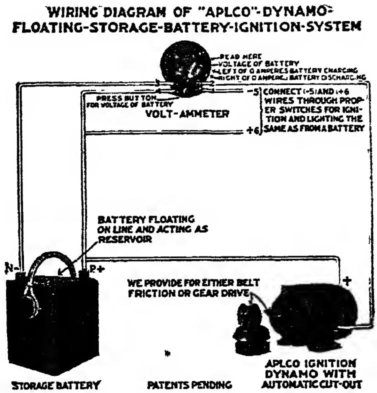


FIG. 351.—"Aplco" dynamo—floating storage battery ignition system—wiring diagram.

THE MAGNETO

Great improvements have been made in magnetos. The K. W. magneto (Fig. 357), manufactured by K. W. Ignition Co., Cleveland, Ohio, here shows the wiring of jump-spark and make-and-

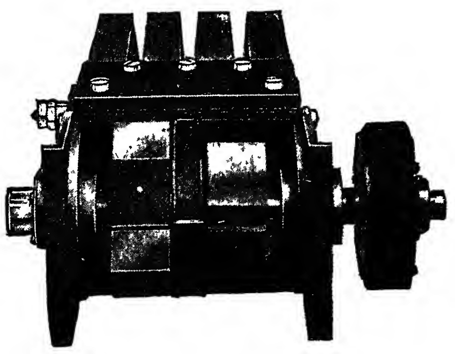


FIG. 352.—K. W. magneto.

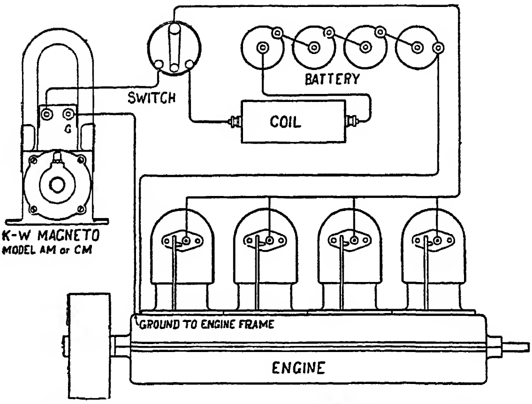


FIG. 353.—Wiring battery and magneto for make-and-break engine.

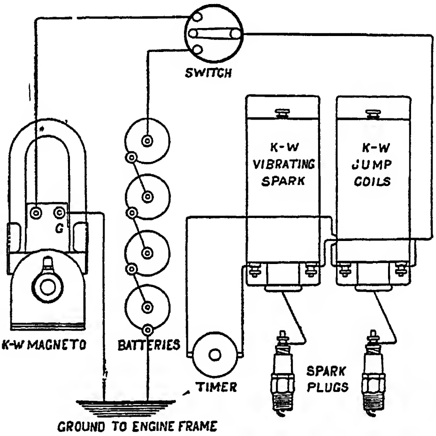


FIG. 354.—Wiring two-cylinder engine, jump-spark, batteries, and magneto

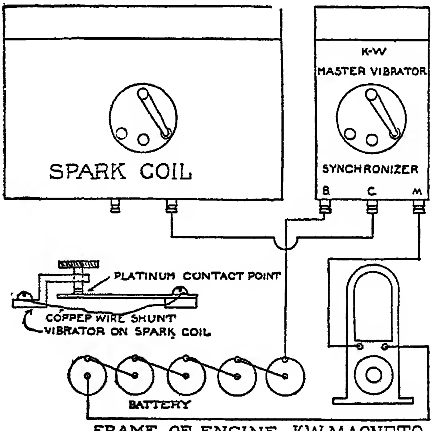


FIG. 355.—Wiring magneto, batteries, and master vibrator—one vibrator for any number of cylinders.

break engines, with double-throw switch, using both magnetos and batteries. This magneto will make a good spark by simply turning over the fly-wheel of the engine by hand, without the use of batteries. Less than one-half turn will give a good spark. It is safe at any speed the engine may run; is very simple, and is not liable to get out of order. With no moving wires, no brushes, in short, nothing to wear out except the bearings, it is as nearly perfect as possible.

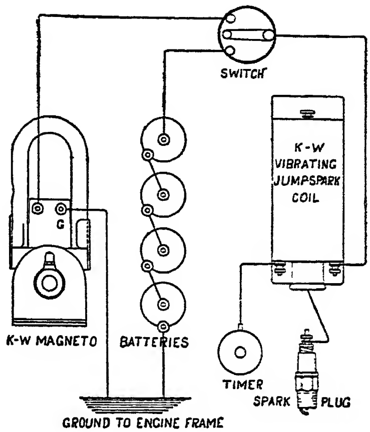


FIG. 356—Wiring jump-spark batteries and magneto, one-cylinder.

In the Ferro Float-feed Carbureter (Fig. 358), the throttle-valve, by means of which the flow of air and gasoline to the cylinder is regulated, is of the butterfly type, controlled by the throttle-lever on the carbureter as shown in Fig. 359.

The automatic action of the auxiliary air-valve is as follows: As the engine turns over slowly, sufficient air is taken in through the regular air-inlet to make the right mixture. However, at a higher speed the motor requires a greater proportion of air. As the speed of the engine increases, there is a corresponding increase in the force of the vacuum created in the cylinders, and this vacuum automatically opens the auxiliary air-valve by forcing down the auxiliary air-inlet spring. In addition to the throttle-lever there are but two other adjustments: the needle-valve, which need only be opened when starting, and the adjusting-screw on the bottom of the auxiliary air-valve. Before starting, the priming float spindle should be pulled. This allows the gasoline to flow out of the spray nozzle, down into the priming-cup. There are small openings in the bottom of the carbureter, immediately

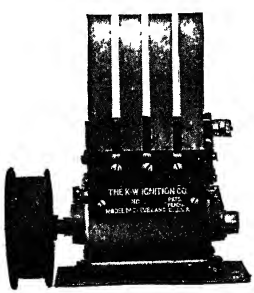


FIG. 357.—K. W. magneto.

under the auxiliary air-valve spring communicating with the priming-cup. When cranking the motor, a certain amount of

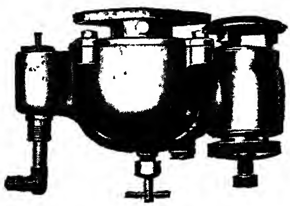


FIG. 358.—Ferro carbureter.

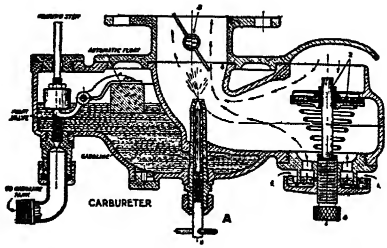


FIG. 359.—Ferro carbureter—sectional view.

air, taken in through the carbureter, goes in at the regular air-inlet and a certain proportion of air is drawn through these holes connecting with the priming-cup. As the priming-cup has been filled with gasoline, the air taken in through this cup is heavily charged with gasoline, making a rich mixture that causes immediate starting.

In the Breeze carbureter (Fig. 360) manufactured by Breeze Carbureter Co., Newark, N. J., the main and auxiliary air supplies are fixed, and require no adjusting. The fuel cut-off is the simplest made and of the fewest parts. The auxiliary air-valve is away from dirt, water, and oil; and does not get stuck. The throttle operates a compensating fuel mixture. All the air serves to break up the mixture. Fig. 360 shows the internal construction of this carbureter.

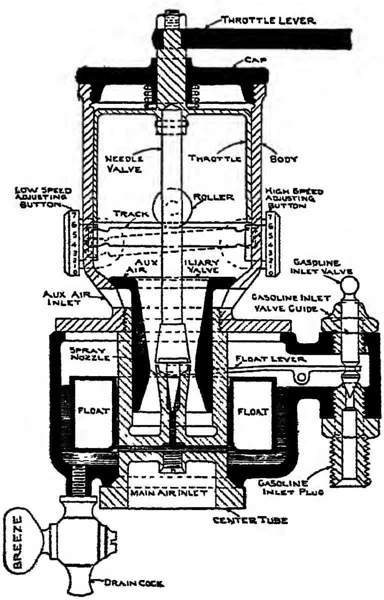


FIG. 360.—Breeze carbureter—sectional view.

GASOLINE TANKS

Safe receptacles for gasoline (see Fig. 361) are of the utmost importance. Gasoline is highly inflammable. In liquid

form it will not explode, but, being a volatile oil, it vaporizes very rapidly; and in its gaseous form it becomes a dangerous explosive when not properly handled. It therefore behooves everyone using gasoline to provide a safe tank for it. A tank which is not properly seamed, brazed, riveted, and soldered, installed in a boat or automobile, is liable to leak at any time. A seamless brazed tank is absolutely safe. The chemical action of gasoline on galvanized tanks often causes leak in soldered or rusted tanks; and for that reason a tank which is tinned on the inside is safer. Again, as tin is not affected by gasoline, one has not to contend with the sediment from the galvanizing clogging the needle-valve of the carbureter—a continual source of annoyance and danger. Manufactured gas used in illuminating is no more dangerous than gasified gasoline. Just as much care should be taken in installing a tank in a boat as in

Fig. 361.—Seamless steel gasoline tank.

piping a house. The boat is subject to vibrations and abuse; and any leakage from a poor tank or through imperfect connection is dangerous.

Fig. 361 represents a tank manufactured by Janney, Steinmetz & Co., Philadelphia, and shows the connections for filling, air, gage indicating amount of gasoline, etc. This style of tank may be used by gravity or air pressure. It is also made for whistles, and is tested at a high pressure.

CONNECTICUT COIL CURRENT INDICATOR

This is manufactured by The Connecticut Telephone and Electrical Co., Meriden, Conn.

Few motorists have the slightest idea why their sparking batteries repeatedly give out and the purchase of new ones becomes necessary after every three or four hundred miles of service, or why storage batteries require recharging equally as often.

This condition of affairs is due to the negligence of the coil manufacturer more than to any other cause, principally because the coils are constructed with little regard for efficiency, and secondly because the average person, when adjusting a coil, has but a trifling conception of what he is doing, the maker having provided no means to enable him to know.

In adjusting a coil (Fig. 362), increasing the tension on the vibrator increases the amount of current passing through the coil; and in the majority of cases coils are adjusted to consume more current than is actually necessary to do the work required of them.

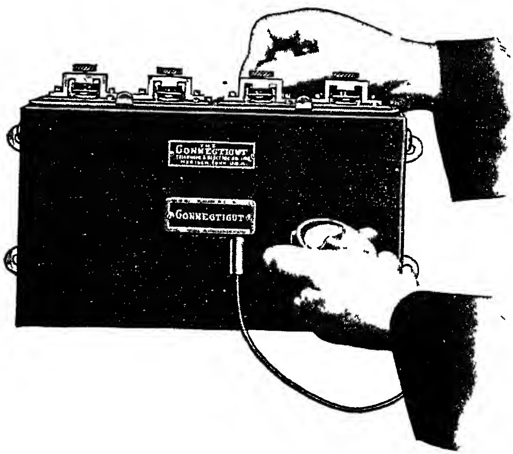


FIG. 362.—Adjusting jump-spark coil.

A properly constructed coil should be designed to take a given amount of current to secure the desired results; the primary and secondary windings, condenser, and core should all be calculated accordingly; and, if the coil is correctly made, and the proper current used to operate it, the result will be the almost total elimination of coil and battery troubles.

A coil will fire a charge perfectly on a given amount of current; and all used over this amount is more than a loss, as the greater the amount of current passing through the coil the quicker the battery becomes exhausted, and the more the sparking and timer contacts burn, causing wear and improper timing.

Fig. 363 shows how the indicator can be used on a lever switch

by placing the lever on the "off" position, and placing plug attached to cord so that the point of plug touches the lever and the body touches the switch point as shown.

In case the indicator needle throws backward, reverse the posi-

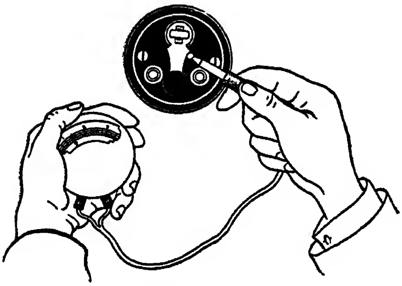


FIG. 363.—Coil indicator used on lever switch.

FIG. 364.—Coil indicator—reversing position of plug.

tion of the plug as shown in Fig. 364, so that point of plug touches the switch point and body of plug rests on the lever.

The sound of the vibrator affords little indication of the amount of current passing. The only sure and safe way to know "where one is at" is by using this indicator, and by it alone adjustments should always be made.

This device consists of a special form of indicating meter, attached to which is a double conducting cord and metallic circuit plug, and with which it is possible at any time to see just how much current you are drawing from your battery.

To operate, remove the running plug, which is the ordinary metallic plug with rubber handle, and push the metallic plug, attached to the meter, into the jack from which the running plug has just been removed. This throws the instrument into circuit and indicates the amount of current passing through the coil.

FIG. 365.—Voltameter, applied to battery for testing.

Fig. 365 represents a voltameter,

designed to show the exact condition of batteries, either storage or dry cells. It is really two instruments in one. The voltage side is used for testing storage-batteries, each cell of which should be tested individually and should show 2½ volts after the battery is fully charged and still charging. If they show less than 1.7 they should be recharged. A storage-battery on open circuit when fully charged should show between 2 and 2.2 volts.

The ampere side is used for testing the condition of a dry battery, each cell of which should be tested separately. If any cell shows less than 6 amperes, it should be replaced with a new one. It should not be forgotten that the successful working of the engine depends greatly upon the condition of the battery.

THE LACKAWANNA MARINE ENGINE

This engine, manufactured by the Lackawanna Manufacturing Co., Newburg, N. Y., may be called a general-purpose, marine engine. Being of medium weight, it answers the purpose of the

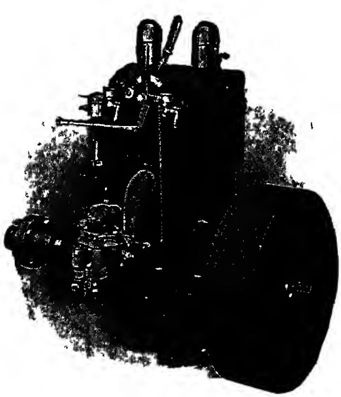


Fig. 366.—Lackawanna marine engine, starboard side.

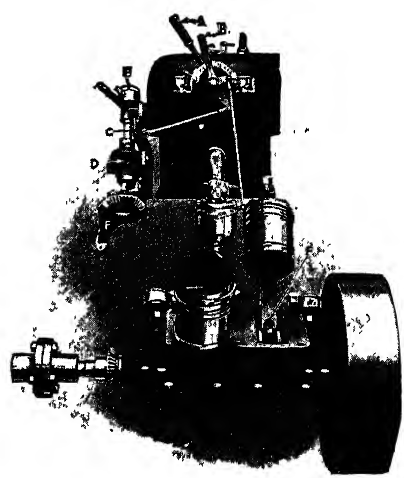


Fig. 367.—Lackawanna marine engine, working parts.

family or pleasure boat, is heavy enough for the working or fishing boat, and is light enough for the speed boat where reliability and lasting service are required. It is made in one, two, three, four,

and six cylinders, from two and one-half to fifty-five horse-power.

The Lackawanna was one of the first two-cycle, three-port engines made, and is a valveless, reversing engine. It has always been considered a high-grade reliable engine, and has been on the market for eleven years. Many improvements have been introduced in the 1910 model. Fig. 366 shows a general view, starboard side. Ignition is jump-spark; the spark-plug covers, as shown, thoroughly protecting the plugs. Fig. 367 shows the working parts. A is the starting and reversing lever; B, the carbureter throttle lever, both of which may be operated from any part of the boat desired; E, reversible contact timer; D, the water circulating pump which is operated by the timer shaft which operates the timer E. The water passes from the pump through C into the water-jacket of the cylinders, insuring uniform expansion of all cylinders and a perfect unobstructed water circulation. There are no openings leading from the circulating water requiring gaskets; and it is impossible for water to enter cylinders or crank-case.

The cylinder, as shown in Fig. 367, may be removed without disturbing the bearings. This design is very convenient; when necessary to insert new piston-rings, the pump, timer, carbureter, controls, etc., are not removed from the cylinders.

During the Hudson-Fulton Celebration races (1909) the hunting-cabin cruiser *Lackawanna,* with a 22-horse-power three cylinder, Lackawanna engine, won second prize with eighteen passengers.

The most important thing to consider in a long-distance race is the ability of the operator to keep the engine constantly running, or rather, the reliability of the engine to run constantly and steadily. An engine to do this must have perfect water circulation and lubrication.

CHAPTER XXII

MOTOR-BICYCLES, TRICYCLES, AND AUTOMOBILES

The great progress made in adapting explosive motor-power to high-speed road-travel during the past few years has accomplished marvellous results in speed and design of road-vehicles. The bicycle and tricycle are now self-running road-speeders, and the automobile of many kinds and names is in range with the steam-locomotive in speed and in racing has outreached all competitors. It has fostered a desire for good roads among our people, resulting in a vast improvement over the rough roads of the olden time. Let the good work go on! As this book is in the line of technical art, the details of automobile-power have been illustrated as far as attainable throughout its pages, and we only give a few examples of reference in this chapter on motor-vehicles. The racing automobiles of a special design for great speed, with a hundred horse-power and a capacity of as many miles per hour, are marvels of this fast age.

THE MOTOR-BICYCLE

In this age of rapid transit, both in commercial and pleasure pursuits, the public are interested in a machine which will carry them at either a high or low rate of speed over all ordinary roads, found in the city or the country.

The bicycle has been enjoyed in the past by thousands of riders who, until then, did not know the pleasures to be found from "a run into the country." There are many now who look back on those days as among the most pleasant they have ever enjoyed. But as the world moves on, so has the demand for more rapid travel with less physical exertion brought to perfection the motor-bicycle.

There is probably no machine which so fully meets the general requirements as the motor-bicycle. It is light; can be driven over

roads impossible to pass in a four-wheeled machine; carried, if necessary, over impassable roads, or propelled by its rider in case of break-downs. For business, it is always ready; is quickly handled; capable of going everywhere, and will "stand without hitching."

For pleasure, it gives the rider the opportunity of seeing the greatest extent of country in the shortest possible time.

The motor-bicycle is not an expensive machine to operate and keep. It costs less than a cent per mile to operate, and does not require a special building or barn, as it occupies but little space, which can be easily spared in any house.

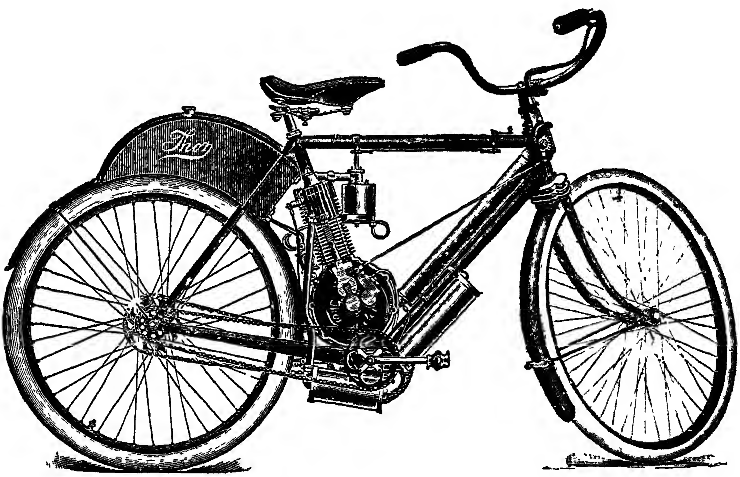


FIG. 368.—The Thor motor-bicycle, made by the Aurora Automatic Machinery Company, Aurora, Ill.

In fact, to sum the whole matter up, all the arguments which are usually brought against the horse and automobile are answered and overcome in the motor-bicycle.

The principal feature in the general construction and design of the Thor motor and component parts is that the main parts are so combined that none of them can be omitted without weakening the general construction, or marring the beauty of the outline.

The frame is not built up complete in itself, and the motor and accessories clamped on, as in many other designs. The motor itself forms a necessary part of the frame. The inlet-tube and the

throttle-device form the support for the carbureter. The wheel-guard forms a support for the tanks; the exhaust-tube a support for the muffler, etc. In this way there is secured, to the greatest possible extent, the stability, compactness, and light weight of the complete machine.

The motor is of the ribbed, air-cooled, four-cycle type, with the exhaust-valve opened by a cam on the reducing-gear, jump-spark ignition, and controlled from the handle by holding the exhaust open and by interrupting the electric current.

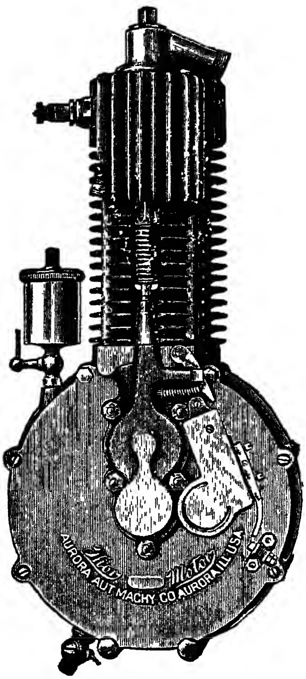


FIG. 369.—Thor motor.

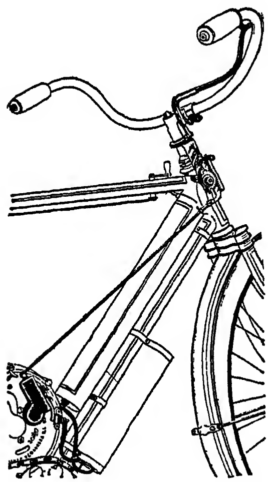


FIG. 370.—Grip-controller and automatic switch.

The tanks holding gasoline and lubricating oil are attached to the machine in a manner that adds to the general symmetry. These tanks are clamped together around the rear stays and supported by the rear-guard. They appear as a part of the frame, and assist, in a large measure, in steadying the entire structure.

The control is in the right-hand grip, and can be operated as easily and as effectively by a child as by a man. It does not interfere with the steering, it being possible to turn the front wheel around, at the same time operating from any angle, or com-

pletely reversed, if desired. It operates both the exhaust-valve and the current, and when shut off the rider unconsciously stops the flow of electric current; this effects a saving in batteries, which up to this time has not been fully appreciated.

The control does away with the wiring through the handle-bar, and all loose wiring around the motor. The automatic switch positively disconnects the electrical circuit when exhaust-valve is lifted.

The battery and induction-coil cases are attached to the lower front bar on the machine in such a manner that they occupy the least possible amount of space, and at the same time are out of the way. They are so situated that the necessary wire-connections are all short and easily accessible.

OPERATION AND CARE OF THE THOR MOTOR-BICYCLE

A few instructions for the operation and care of the motor-bicycle may be appreciated by the novice as well as by the expert.

When starting out for a ride, fill the gasoline-tank, using from 74 to 76 test gasoline. A pocket-tester for this purpose may be secured from any dealer in automobile or motor-bicycle supplies. When filling the tank, use a funnel with a strainer. A lower-test gasoline can be used, but the best results, especially in cold weather, are secured from the higher test.

Fill the lubricating oil-tank, using a high grade of cylinder-oil. Open the oil-tank valve, and allow the oil to flow into the oil-cup. When the cup is full, close this valve, and open oil-cup valve, allowing the oil to flow into the base of the motor. This will lubricate all the working parts automatically, and will last from twenty-five to thirty-five miles, ordinary riding. Owing to the high speed of the motor, a better grade of cylinder-oil than is generally used in automobiles is desirable.

Examine all electrical connections, making sure they are clean, properly attached, and tightened. Investigate the battery. It should contain at least four and one-half volts, and should not run below two or three ampères. A set of batteries will last for about 1,500 miles with ordinary care and usage.

See that all the screws and connections are properly tightened.

Open valve between gasoline-tank and carbureter.

If the machine has been standing out in freezing weather, the piston will work hard, and the inlet-valve may stick. To release the valve, press down the spring-cap on top of the exhaust-dome. Should this not overcome the trouble, unscrew this cap, and a little gasoline dropped into the dome while valve is depressed, and machine is slightly pushed forward, will make the motor start easily.

Replace the cap, and insert switch-key, which must be clean; see that the regulating-pins on top of carbureter are turned toward the letter S; press down the priming-pin in the carbureter, and admit fresh gasoline. Mount the machine and pedal, at the same time turning the right-hand grip to the left. This will close the exhaust-valve, connect the current, and the motor will start. Continue pedalling a few turns after the motor has started, as this will greatly relieve the strain, which naturally occurs when putting motor into full action.

Upon returning from a trip of from twenty-five to thirty-five miles, or if on a journey exceeding this mileage, while the motor is still hot, open the exhaust-valve at the bottom of the motor-base, and drain off the old lubricating oil.

When the machine is not in operation, the valve from the gasoline-tank should be kept closed, and the switch-key removed.

Chains should be kept adjusted tighter than on the ordinary bicycle, and well lubricated.

If any trouble occurs on the road, it is either due to the insulation, electrical connections, or to the spark-plug being fouled. These parts should be carefully investigated and cleaned. There may, of course, be other reasons, but from actual experience it has been found that the above reasons cover the majority of troubles.

Rules and regulations may be laid down, but of all the rules, reasonable care, cleanliness, and, above all, common-sense, will enable the rider to enjoy every mile of his ride.

With proper care and precaution, the motor will start at a moment's notice at any time, rain or shine, day or night, summer or winter, and carry its rider swiftly and silently to destination.

THE MITCHELL MOTOR-BICYCLE

We illustrate in Fig. 371 a motor-bicycle made by the Wisconsin Wheel Works, Racine, Wis. The general model is of the ordinary type with a diamond tube-frame with stronger reinforcements than used in the foot-power machines. The motor is of the ribbed four-cycle type for air-cooling with a 3-inch × 3-inch diameter and stroke cylinder. The motor runs up to 1,400 revolutions per minute; it drives the bicycle by a rawhide band and pulleys of varying sizes, suitable for heavy and light road-work, or hill climb-

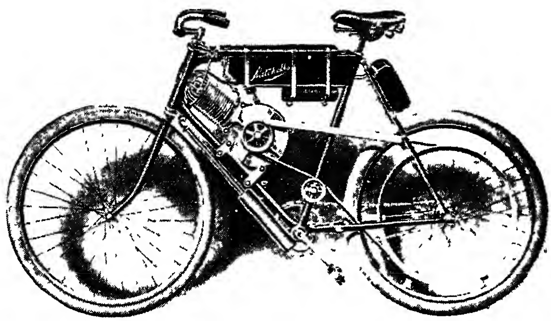


FIG. 371.—Motor-bicycle.

ing. An adjustable tightening-pulley makes the one band suitable for all speeds. Weight of the complete outfit, 120 pounds. Tank supply, seven pints of gasoline, which gives a mileage of from sixty to seventy miles. The ignition is by jump-spark from a pair of dry batteries attached to the frame behind the seat and an induction coil under the seat, the gasoline being stored in a narrow case inside the frame near the motor.

A lever convenient to the right hand lifts the exhaust-valve for ease of starting and allows of coasting with the gasoline cut off, thus cooling the motor and saving fuel.

The motor-tricycle, so greatly popular in France, and for a time popular in the United States, for a single rider, has been partially superseded by the motor-bicycle. Its freedom from balance-care and breakage from overturning still recommends it as a comfortable light vehicle.

The De Dion-Bouton carbureter and motor for tricycles are

detailed in sections in Fig. 372. In the vaporizing-carbureter the air enters through the tube A, spreading over the surface of the gasoline and under the plate B, which is adjustable to the varying height of the gasoline by sliding the tube in the socket at A. The same tube carries a wire and float for indicating the height of the fuel. Additional air for regulating the mixture is drawn in through the regulating-cock at C, and shown in detail in the small section

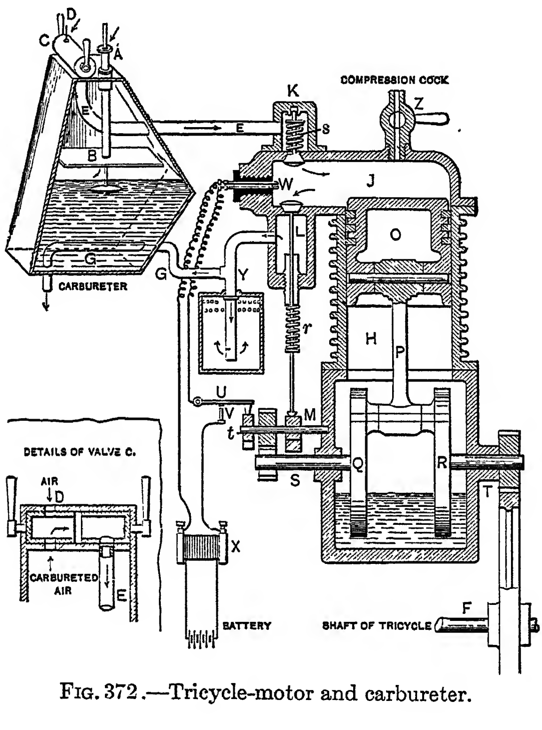


FIG. 372.—Tricycle-motor and carbureter.

at the lower left-hand corner of the cut. The diluted mixture is further regulated in its passage to the cylinder by the cock in the right-hand chamber of the section.

A part of the exhaust is passed through the carbureter by the pipe G to avoid excessive cooling of the gasoline by evaporation. The details of the motor parts are self-explanatory.

The vehicle-motors of the Brennan Motor Company, Syracuse, N. Y., are standardized for the special service of light vehicles of the runabout class and for the finer styles of automobiles for high

speeds. Their air-cooled, five-horse-power, two-cylinder motor for runabout service is a model of compactness, lightness, and power.

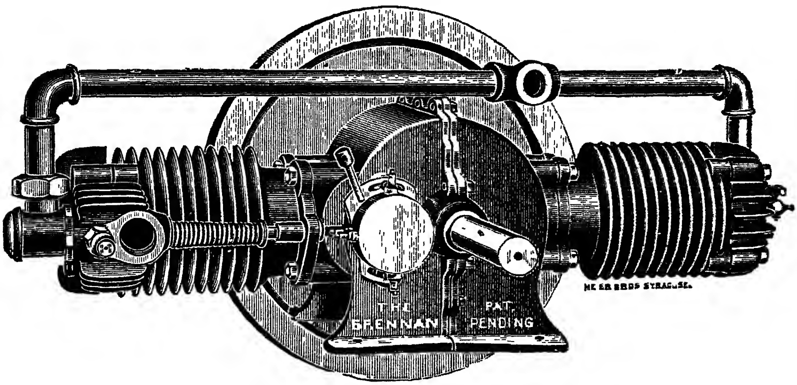


FIG. 373 —5-horse-power, light-weight, air-cooled runabout motor.

The balanced method of construction by the opposed cylinders gives absolute freedom from vibration by the simultaneous im-

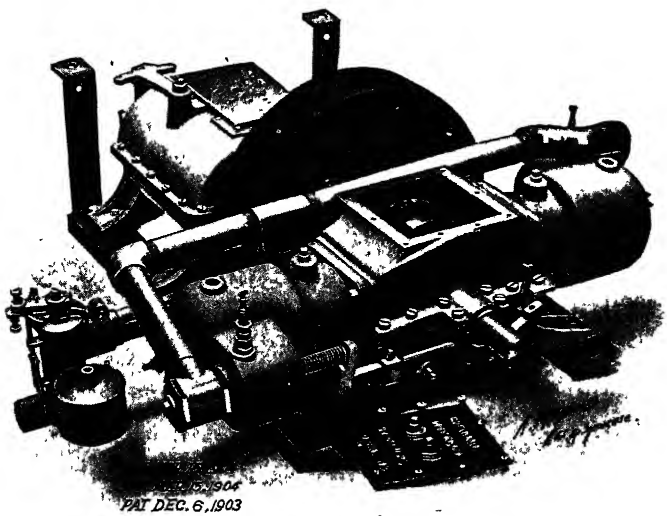


FIG. 374 —Water-cooled motor, 8 to 30 horse-power.

pulse from opposite pistons and opposite rotative forces. The water-cooled motors especially designed for high-class automobile

service are illustrated in Fig. 374, and a section of the detailed parts in Fig. 158. It has a three-speed sliding-gear direct in line of the shaft with a clutch fitted to the balance-wheel. They are operated at 90 pounds compression, and in motors from six to sixteen horse-power have a range of speed of from 150 to 1,300 revolutions per minute. Those of twenty and thirty horse-power have

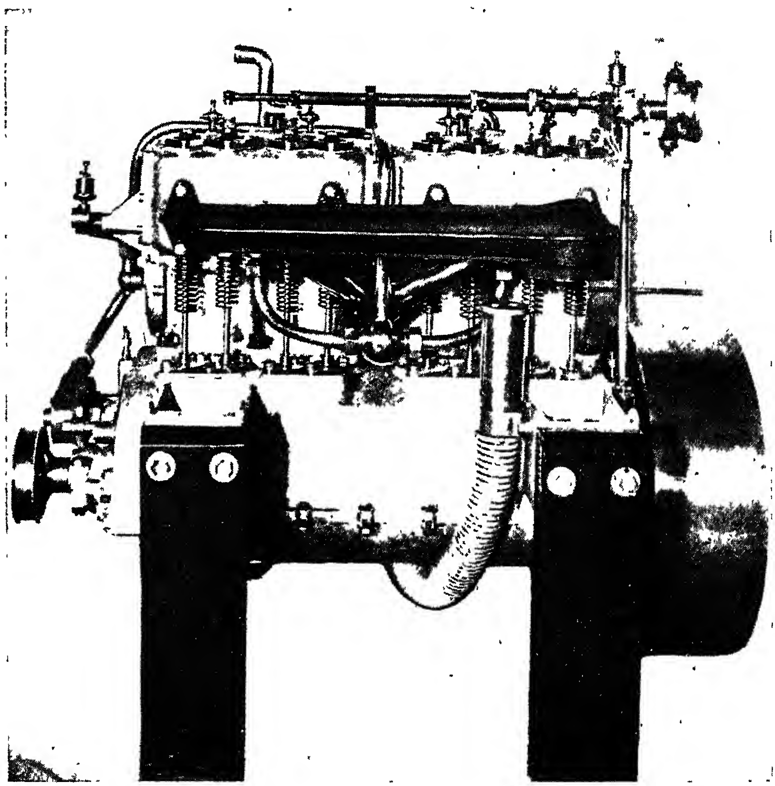


FIG 375.—Chadwick light auto-motor.

a speed-range of from 100 to 1,100 revolutions per minute. The vertical multicylinder motors of this company, in units of twelve, eighteen, and thirty-two horse-power, are on the high-speed grade and variable to meet automobile requirement. They are furnished with three-speed sliding-gear direct in line with motor-shaft, clutch fitted to balance-wheel.

In Fig. 375 we illustrate the Chadwick automobile and marine motor, built by the Fairmount Engineering Works, Philadelphia, Pa. Their motors for special service are the lightest made, having copper water-jackets and aluminum base.

The twenty-horse-power auto-motor with four cylinders, four and one-sixteenth by five inches, complete with fly-wheel, weighs 315 pounds, or less than sixteen pounds per horse-power, with speed variation of from 100 to 2,000 revolutions per minute. The twenty-four-horse-power auto-motor, with four cylinders, four and one-half by five inches, complete as above, weighs 450 pounds, or 18.7 pounds per horse-power; speed variation of from 100 to 2,000 revolutions per minute. The forty-horse-power auto-motor, with four cylinders, five by six inches, is a marvel of lightness, weighing but 460 pounds, or 11½ pounds per horse-power.

THE HENRICKS MAGNETO AND GOVERNOR

In Figs. 376 and 377, we illustrate one of the latest novelties in ignition appliances; a magneto generator and governor in which the speed of the armature is so controlled by a centrifugal governor

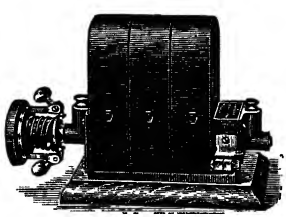


Fig. 376.—The Henricks magneto.

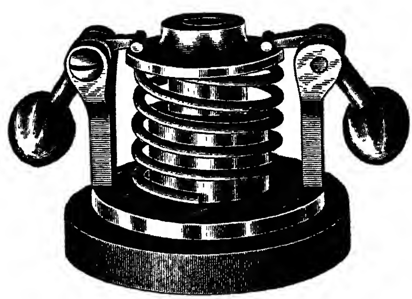


Fig. 377.—Dynamo governor and friction-disk.

on its own shaft, that the variation of the motor-speed does not affect the speed of the armature.

The governor consists of a friction-disk held to the fly-wheel of the engine by means of a spring. The pressure of the spring holding the friction-disk to the fly-wheel is controlled by the centrifugal action of the governor-balls, so that as the speed in-

creases, the balls expand and loosen the tension of the spring against the friction-disk, thus slowing down the speed of the armature and the contrary when the engine-speed slows.

In this manner by the slipping of the friction-disk the speed of the armature is made uniform within very narrow limits and thus insuring a steady and powerful electric-sparking current, so desirable for the uniform action of explosive motors. The irregular speed of the armature of an ignition dynamo, when driven at the varying speed of the motor on automobiles and launches, makes one of the troubles in firing the explosive charge not easily found or accounted for and which makes this governor a most desirable adjunct of every sparking dynamo for controlling its speed when driven from a variable-speed motor. These magneto dynamos and governors are made by the Henricks Novelty Company, Indianapolis, Ind.

CHAPTER XXIII

KEROSENE, DISTILLATE, AND PETROLEUM-OIL MOTORS

THE incentive to explosive-motor design in the line of economy of power has been the means of producing remarkable results in the adaptation of the use of the cruder and cheaper fuel-oils for motive power. The rise in the cost of gasoline gave an impetus to experiments for utilizing the heavier petroleum products, and kerosene and distillate came into successful use, and finally crude petroleum in its cheapest form is at the head of fluid fuel as an all around and portable element of power and obtainable the world over.

For stationary motive power there is a further economy in the producer and blast-furnace gases that is greatly expanding the field of operation for the explosive motor and will continue during the coming years, when its power, like that of steam, will become stationary in its economical progress.

Much detail of oil-motors is also described and illustrated in previous chapters of this work.

In Fig. 378 is illustrated a view of the kerosene-oil engine of the International Power Vehicle Company, Stamford, Conn.

The kerosene-engine differs from the gasoline-engine in essential details of its mechanism, due to the different natures of the two fuels. Kerosene being less volatile, no carbureter is used to convert the fluid into gas. The oil is introduced into the cylinder as a spray, mixed with air, and is changed into a gaseous condition within the cylinder before ignition occurs by means of heat which must be within well-defined limits. If the vaporous fuel comes in contact with too great a heat the petroleum is disintegrated, its hydrogen escapes, and its carbon deposits in stone-like scales upon the cylinder-head, while too little heat will not produce the gaseous condition necessary to perfect combustion.

The engine is shown in Fig. 379, and Fig. 380 in section, show-

ing the position of the piston when ignition is taking place, and when the exhaust-gases are escaping and the fresh charge entering. When the piston has risen nearly to the end of the upward stroke the air-inlet A is uncovered, and as there is a partial vacuum in the air-tight crank-case C, the air rushes in. As the piston descends, impelled by the ignited gases, the air in the crank-case is compressed, the pressure extending to the passage D. The descending piston finally uncovers the exhaust-passage, through which the inert gases of combustion escape, impelled first by the pressure remaining in the cylinder, and then by the rush of air through the inlet E, which is opened after the exhaust, as will be noticed in Fig. 380. The moment the inlet E is opened the compressed air in the crank-case and air-passage rushes into the cylinder, driving out the remaining gases, except a small amount left in the cavity holding the firing-plug F. This small residue plays an important part in the successful operation of the engine, for it keeps the new charge away from the red-hot firing-plug until the proper time for igniting. As compression takes place above the piston during its upward stroke, the new charge forces the burned gases farther into the cavity, until the new charge comes in contact with the plug and is ignited. The plug has a screw-stem, by which its position in the cavity may be adjusted by a nut on the outside

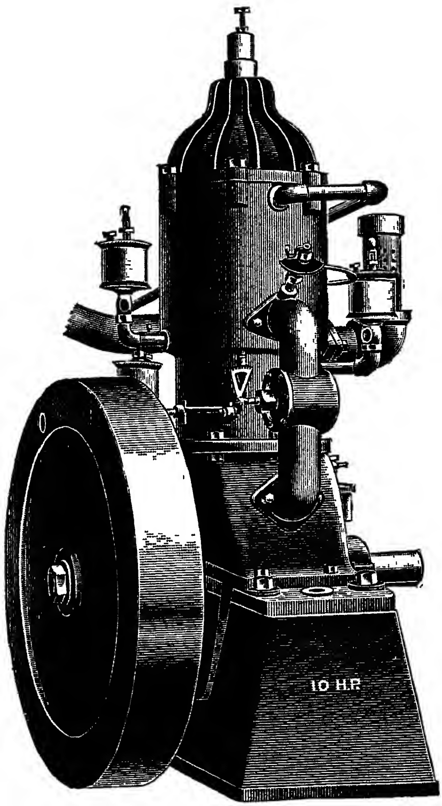


FIG 378.—Kerosene-oil engine.

of the cylinder-head to correspond to the power required. Withdrawing the plug into the cavity delays ignition, thus furnishing greater power. Advancing it nearer to the opening of the cavity advances the ignition, and less power is developed.

The charge of fuel is introduced through the inlet B, either from a pressure-tank or by the suction created by the partial vacuum of the crank-case. A check-valve prevents the oil from returning through B after it has been admitted. The oil as it enters the engine is received on a gauze screen H, and by capillary attraction forms a thin film upon it until the entrance E is uncovered and the air rushes into the cylinder, passing through the gauze, taking the oil with it in a very fine spray, so fine that if permitted to escape into the air it would float. The intermingled air and oil-spray passing up into the cylinder strikes the hot cylinder-head at

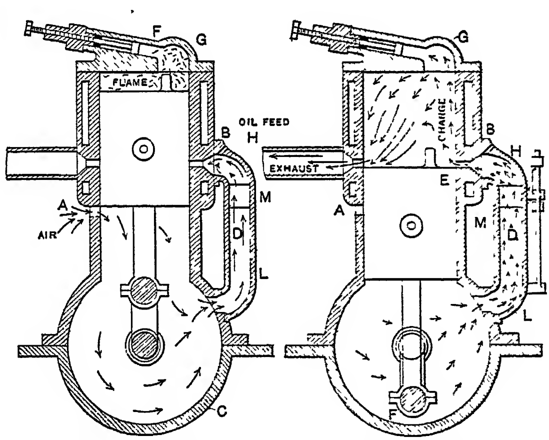


FIG. 379.—Ignition. FIG. 380.—Exhaust.

G. The heat of the metal is not enough to ignite the oil, nor to cause it to "crack," *i.e.*, give off hydrogen and deposit carbon. Instead, this heat converts the oil and air into a gaseous mixture, which is maintained by the heat of compression until the moment of igniting.

The ignition-plug replaces the torch, which need be applied only in giving to the plug its initial red heat for the first discharges, after which the heat of ignition is all that is necessary.

For changing the speed of the engine a butterfly-valve, shown at M, Fig. 380, in the air-transfer box, is employed for throttling and is automatically controlled by the governor, which is of the usual type.

In Fig. 381 is illustrated their marine motor, of the kerosene-oil type, which is of the same design as the stationary motor. The perforated tube projecting below the exhaust-opening is a protecting cover to the air-inlet A, as before described. A reversing-

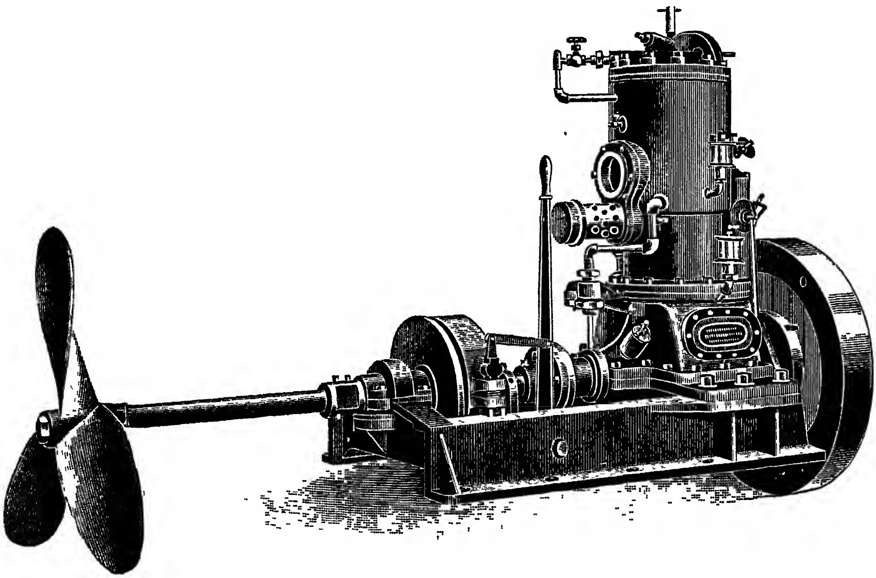


Fig. 381 —Kerosene-oil marine engine.

gear controlled by a lever is used in connection with a solid three-blade propeller.

NEW YORK KEROSENE MARINE MOTOR

Fig. 382 illustrates a marine engine built by the New York Kerosene-Oil Engine Company, New York City. This engine is provided with a combustion-chamber B, into which kerosene is injected through an atomizer A. A lamp L is used to heat the chamber B, preparatory to starting. The air inlet-valve and the exhaust-valve are actuated by cams in the ordinary manner

on a secondary shaft, the engine being of the four-cycle type. The injection of oil is accomplished by the pump D, actuated by one arm of a rock-lever, which is oscillated by a cam on the secondary shaft.

The charge of kerosene is regulated by the stroke of the pump, which is controlled by a lever in the marine motors and by a governor in stationary motors.

The injection of the oil is in a very fine stream under considerable force, by which it is atomized in the hot-chamber B. The blow-pipe lamp L is made permanent in the stationary engines with an air-pressure combination for gas or gasoline. In the marine motors a tank air-pressure kerosene-torch is used which heats the combustion-chamber ready for starting the motor in about five minutes. The clearance is so adjusted that the compression is carried to eighty-five pounds, at which point, or just before the piston reaches the dead centre, the charge of oil is suddenly injected and vaporized by the heat of compression and the walls of the vaporizing-chamber. By the late injection of the oil preignition is impossible, and the atomizing of the oil being instantaneous is followed by its perfect vaporization in its mixture with the hot air. The firing of the charge of partially mixed oil-vapor and air is exact and instantaneous as to time, and owing to the small volume of the clearance space carries the pressure up to about 190 pounds, and by continuous combustion during the impulse-stroke gives a higher expansion-curve than is due to the adiabatic

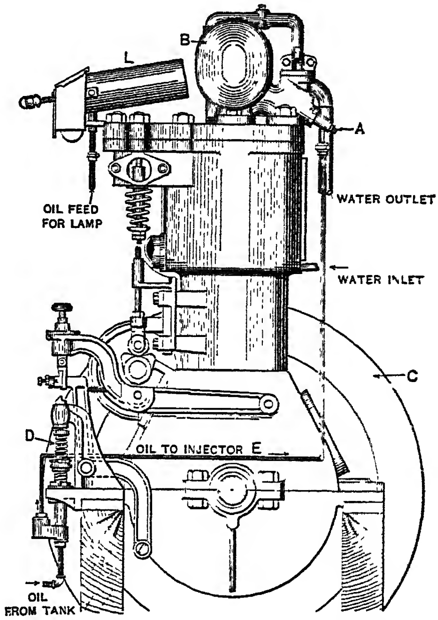


FIG. 382.—New York kerosene marine motor.

line, and showing by the indicator card a mean effective pressure of seventy-four pounds. This exceeds the usual mean pressure in gas and gasoline explosive motors. These motors are built in sizes of two, five, ten, and twenty horse-power, with one, two, and four cylinders.

In Fig. 383 is illustrated a section of the kerosene-oil motor of the American and British Manufacturing Company, Providence, R. I.

It will be noticed that the ignition is accomplished by the usual ignition hot-dome D, at the upper end of the cylinder, the dome being protected by a damper-cap to prevent heat radiation after the engine is started. A concentric cap fits over the inner cap. When both apertures coincide, the heating-lamp for starting is placed inside; after starting, the outer cap is rotated till the apertures are covered.

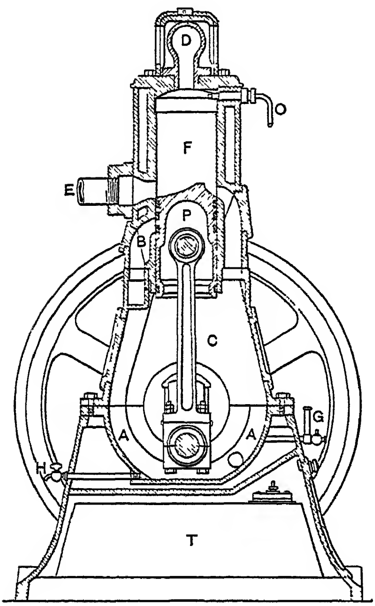


FIG. 383 —Section of oil-motor.

The operation of the engine is as follows: the ignition-dome D is heated for five minutes or more by a Primus kerosene blue-flame torch, then the handle of a small oil-pump is operated a few times, to force the oil up from the tank T through the nozzle O into the cylinder F. One or two quick turns of the fly-wheel are given, then the engine starts.

On the up stroke of the piston P, air is drawn in through two holes A in the base, and follows the piston through the port B into the crank-case C as soon as the piston uncovers the port. On its descent the piston slightly compresses this air in the crank-case until its upper end uncovers the exhaust E and also the air-inlet, then the exhaust-gases pass out of E, and by the curved top of the piston the air from the crank-case is projected upward at the same time into the cylinder and locked there upon the upward

stroke of the piston P, which closes the air-inlet and exhaust-port E.

The air in the cylinder is then further compressed and heated by the continuation of the up stroke of the piston, and just as the latter is about to descend a minute quantity of kerosene is injected by the oil-feed pump and is immediately vaporized and mixed with the air, forming an explosive mixture that is in turn ignited by the hot dome D, the explosion driving the piston downward. The combustion is so perfect that the cylinder always remains clean

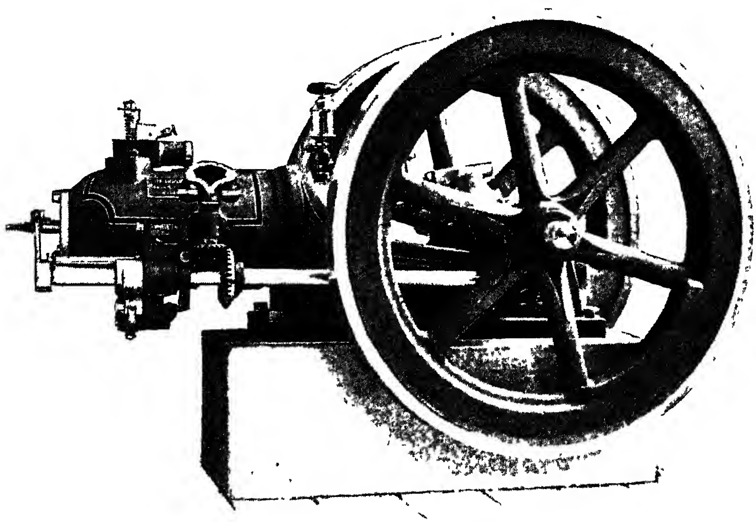


FIG. 384.—The Doack motor, 3 to 10 horse-power.

and the piston is never clogged by soot. There is thus a positive entrance of the air and oil to the cylinder in regular sequence. G is an oil-well for one of the main bearings, and H is a faucet for drawing off the oil collecting in the bottom of the crank-case.

An eccentric on the main shaft with a variable throw, regulated by a simple governor, changes the stroke of the oil-feed pump to suit the load. The engine responds very quickly to the varying quantities of fuel it receives, and the governing action is consequently positive and very close. This results in high efficiency, and makes it possible to obtain a brake horse-power with 0.7 to 0.8 pound of oil, or a little less than a pint.

The gas, gasoline, and oil engines of Henshaw, Bulkley and Company, San Francisco, Cal., are of compact and neat design, and embrace some novelties of simplicity of parts that obviates some of the troubles of complex parts in explosive-motors. The frame, cylinder, and cylinder-head are cast in one piece and are mounted upon a stone or concrete sub-base, which with its weight makes a very solid foundation. The cylinder and head being in one piece, the troubles of water-leakage into the cylinder are entirely overcome.

The fuel and air-inlet valves are in a separate casting, bolted to the top of the cylinder, so as to avoid a side-chamber and its

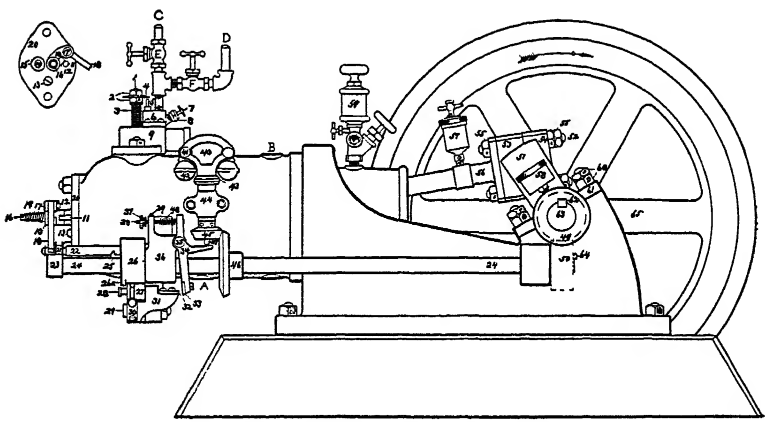


FIG. 385.—Details of the motor parts.

C. Distillate-pipe. D. Gasoline-pipe. 1. Admission-valve. 2 Admission-nuts 3 Admission-spring. 4. Admission-cap. 5. Fuel-valve 6. Fuel-valve casing. 7. Needle-valve. 9. Admission valve-chest. 26. Exhaust-cam. 27. Exhaust-roller. 28. Exhaust roller-stud. 29. Exhaust-lever stud. 30. Exhaust roller-shipper and knob 31. Exhaust-lever. 32. Exhaust-lever steel tongue. 33. Governor latch-blade. 34. Governor-latch, bell-crank. 36 Cam-shaft bracket. 37. Governing spring-nut 38. Governing spring-rod.

extra wall-surface. The exhaust-valve is on the underside of the cylinder with its seat water-jacketed. The governing is by holding open the exhaust-valve and making a hit-or-miss charge.

The governor is a very neat device. A three-arm bell-crank, on the centre arm of which the governor acts by a push-rod, pressing it down against a spring and regulating-nut, on the upper arm, causing the lower arm to push the roller of the exhaust-valve lever onto a high section of the cam and thus holds open the exhaust-valve until relieved by the governor.

The fuel used is gas, gasoline, kerosene, or distillate. When kerosene or distillate is used the engine is started with gasoline. With crude oil a retort heated by the exhaust is used.

The engines were designed by Mr. John E. Doack, and are known as the Doack engines.

KEROSENE-OIL ENGINES

In Fig. 386 we illustrate in sections the details of the new style Mietz and Weiss kerosene-oil engine. The new feature is the use in

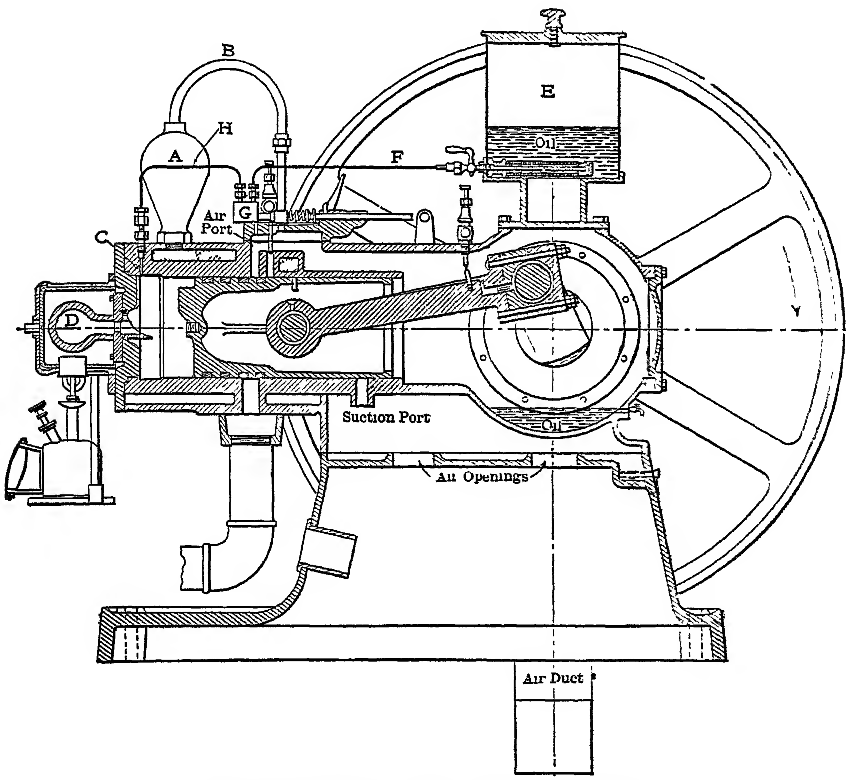


FIG. 386.—Section of steam, air, and oil-engine.

the cylinder of steam generated in the water-space of the cylinder-jacket, which is different from all other explosive motors in principle and effect.

It utilizes a large part of the heat ordinarily lost through the

cylinder-walls and cooling-water, and considerably reduces the trouble from deposition of carbon in the cylinder (probably by

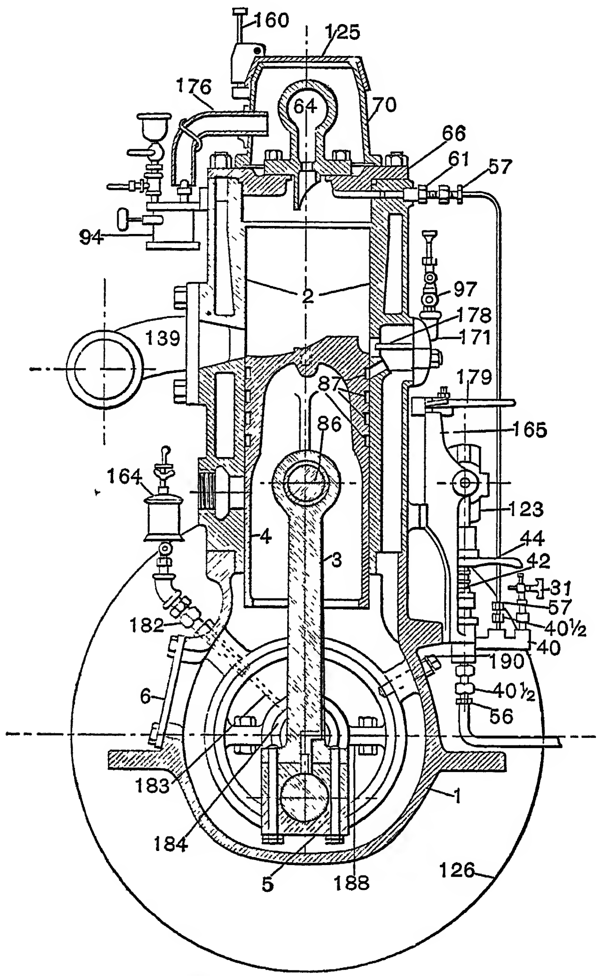


FIG. 387.—Mietz and Weiss marine oil-engine.

REFERENCES: 34. Ignition-ball. 70. Mantle. 125. Damper. 160. Damper-regulator. 176. Blow-pipe. 94. Lamp. 61. Oil-injection. 179. Regulator-handle. 42. Oil-pump plunger. 44. Oil-pump handle. 31. Air-relief cock. 40½. Suction and pressure oil-valves. 123. Centrifugal governor operating the throw of the pump-plunger. The other parts shown are self-explanatory as to the general arrangement of the two-cycle engine.

the dissociation of the water-vapor furnishing oxygen to the hot particles of carbon).

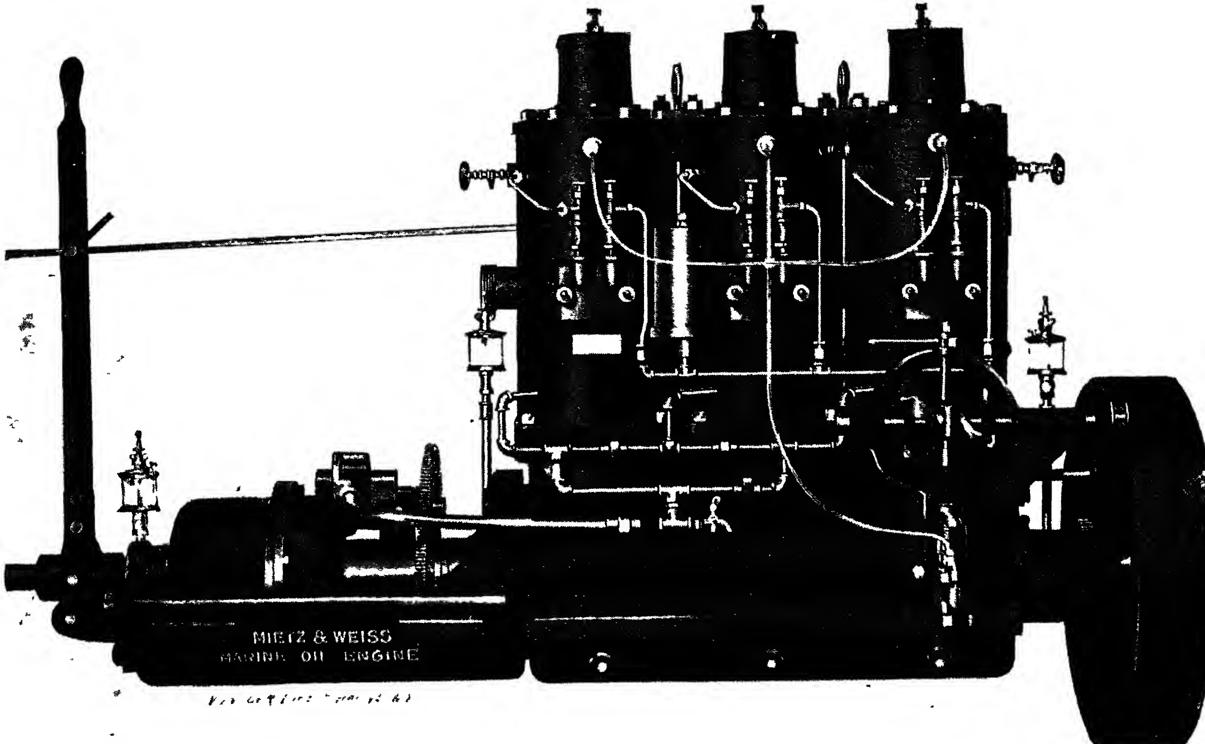


FIG. 388.—Three-cylinder marine oil-engine, 22 to 45 horse-power.

The new parts are a small steam-dome A, a short steam-pipe B, connecting the steam-dome with the air-port, where it is admitted with the charge of air into the cylinder, when the piston is at the forward end of the stroke. When the piston reaches the correct position, a small quantity of oil is drawn by the oil-pump G through the pipe F from the oil-tank E, and delivered through the pipe H to the opening C, where it falls upon the lip of the red-hot igniter-ball D, and is exploded along with the air and by its heat dissociates the steam, which adds further elements of combustion to the unconsumed carbon; thus increasing the mean pressure of the expansion-curve.

An efficiency is claimed for the steam, air, and oil mixture of from fifteen to twenty per cent. higher than for the oil and air mixture alone, the total thermal efficiency in a test being forty-four per cent. with a compression pressure of 100 pounds gauge, and 170 pounds explosion pressure by gauge, using one pint of oil per brake horse-power per hour.

The tests were made on a fifteen-horse-power engine of the two-cycle type in which the air is drawn into the crank-case, during the compression-stroke through the suction-port from the engine-base; is compressed during the impulse-stroke and passes through the side-port, taking a portion of steam in its passage. Since there is no circulation through the water-jacket, the level of the water in the jacket is maintained at a constant level by a float-trap in a side compartment, and only water is fed to equalize the evaporation, with a water temperature just below the boiling-point and which has been found to be the best working temperature for an explosive motor.

In Fig. 387 we illustrate a sectional view of the Mietz and Weiss vertical marine oil-engine with reference figures showing the detail parts. Kerosene oil, the most economical and conveniently obtained fuel for explosive-motor service, has been the incentive for bringing the oil-engine to its utmost perfection in design and working power, and for marine motors, safety as well as economy has made it of primary importance for launch, yacht, and auxiliary service.

THE HORNSBY-AKROYD OIL-ENGINE

This engine is of English origin, the invention of Mr. H. Akroyd Stuart, who has lately made many improvements in its design by perfecting the charging-mixture. It is built in the United States

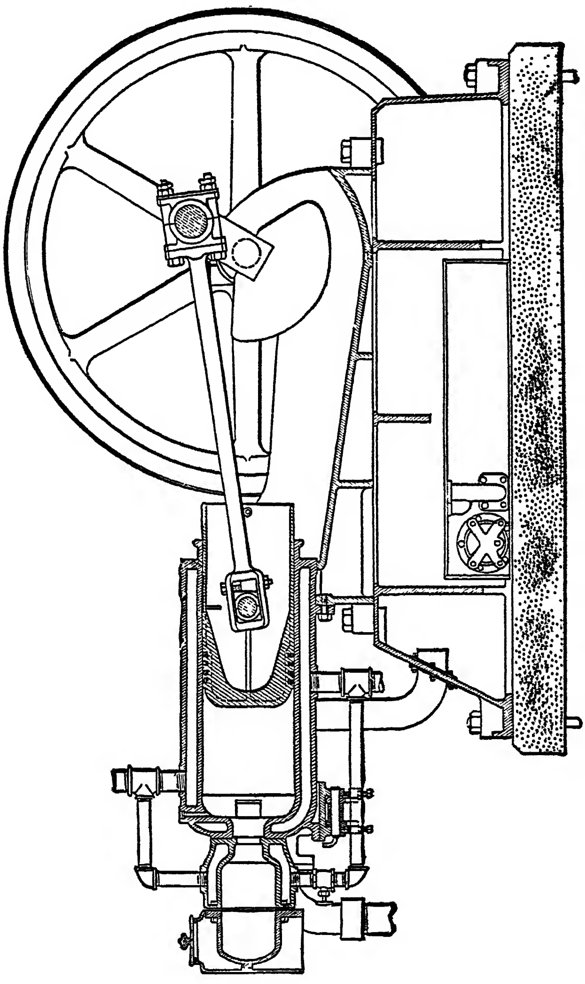


FIG. 389.—Sectional elevation, Hornsby-Akroyd oil-engine.

by the licensees of the United States patents, the De La Vergne Refrigerating Machine Company, New York City.

These engines are of the four-cycle compression type, using kerosene and any of the heavy mineral oils as fuel.

In Fig. 389 is shown a sectional elevation, details of design of the cylinder, piston, combustion-chamber, and its case. It may be noticed that the combustion-chamber is made in two parts, flanged together, so that by a special water-jacket the front half is kept cool and to limit the firing-plane in the combustion-chamber to a definite position. The oil-reservoir, located in the base of the engine, is partitioned to allow of traversing the intake-air over and around the oil to take any vapors or odors from the oil and constantly sweep them into the cylinder.

An extension of a chamber from the cylinder-head, somewhat resembling a bottle with its neck next to the cylinder-head, performs the function of both evaporator and exploder. Otherwise these engines are built much on the same lines of design as gas and gasoline engines, having a screw reducing-gear and secondary shaft that drives the governor by bevel-gear.

The bottle-shaped extension is covered in by a hood to facilitate its heating by a lamp or air blow-pipe, and so arranged as to be entirely closed after the engine is started, when the red heat of the bottle or retort is kept up by the heat of combustion within. The narrow neck between the bottle and cylinder, by its exact adjustment of size and length, perfectly controls the time of ignition, so that of many indicator cards inspected by the writer there is no

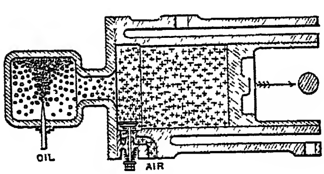


FIG. 390.—Injection, air and oil.

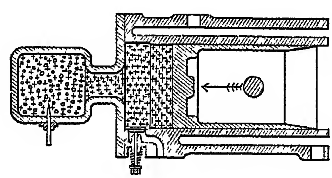


FIG 391.—Compression.

perceptible variation in the time of ignition, giving as they do a sharp corner at the compression terminal, a quick and nearly vertical line of combustion, and an expansion curve above the adiabatic, equivalent to an extra-high mean engine-pressure for explosive engines.

The oil is injected into the retort in liquid form by the action of the pump at the proper time to meet the impulse-stroke, and in quantity regulated by the governor. During the outer stroke

of the piston, air is drawn into the cylinder and the oil is vaporized in the hot retort. At the end of the charging-stroke there is oil-vapor in the retort and pure air in the cylinder, but non-explosive. On the compression-stroke of the piston the air is forced from the cylinder through the communicating neck into the retort, giving the conditions represented in Fig. 390 and Fig. 391, in which the small stars denote the fresh air entering, and the small circles the vaporized oil. In Fig. 391 mixture commences, and in Fig. 392 combustion has taken place, and during expansion the supposed condition is represented by the small squares. At the return stroke the whole volume of the cylinder is swept out at the exhaust, and the pressure in the retort neutralized and ready for another charge.

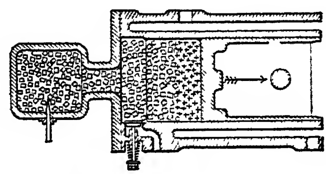


FIG. 392.—Combustion and expansion.

It is noticed by this operation that ignition takes place within the retort, the piston being protected by a layer of pure air.

It is not claimed that these diagrams are exact representations of what actually takes place within the cylinder; nevertheless, their substantial correctness seems to be indicated by the fact that the piston-rings do not become clogged with tarry substances, as might be expected.

This has been accounted for by an analysis of the products of combustion, which shows an excess of oxygen as unburned air; which indicates that the oil-vapor is completely burned in the cylinder, with excess of oxygen.

THE DIESEL MOTOR

This motor is an innovation upon all former ideals in explosive power and indicates the "Ultima Thule" of explosive-motor compression, and possibly the limit of fuel economy in this type of prime movers. Mr. Diesel has attempted to realize, within the limitations of practice, an approach to the conditions of the "Carnot cycle" by the production of a motor of very high thermal efficiency. In order to accomplish this result it was evident that a much higher degree of compression was necessary than that used in

existing motors, since it was demanded that the charge be compressed adiabatically to the maximum initial pressure at which the motor was to be operated, this pressure not to be exceeded by the gases generated during the combustion. Such a compression would naturally produce an increase in temperature sufficient to ignite the combustible, and hence it became apparent that the fuel must not be introduced with the air, but that the air must first be compressed adiabatically and that the fuel must then be introduced and burned during the out-stroke of the piston isothermally, if the desired cycle was to be practically realized.

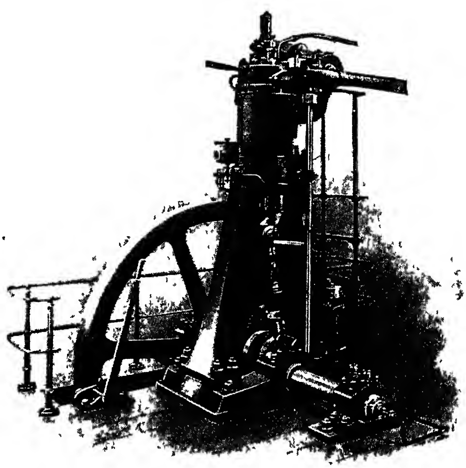


FIG. 393.—The first German Diesel motor.

In the Diesel motor the high temperature attained by the compression of the air is sufficient to provide for the ignition of the combustible, and it is only necessary for the fuel to be injected into the heated air for its ignition and combustion to take place.

In his theoretical discussion of the subject, Mr. Diesel laid down four conditions as essential to the realization of the highest economy:

First, that the combustion temperature must be attained not by the combustion, and during the same, but before, and independent of it, by the compression of pure air.

Second, that this is best accomplished by deviating from the

pure Carnot cycle to the extent of combining two of the stages of the cycle, and directly compressing the air adiabatically, instead of first isothermally from two to four atmospheres, and then adiabatically to thirty or forty fold.

Third, that the fuel be introduced gradually into the compressed air, and burned with little or no increase in temperature during the period of combustion.

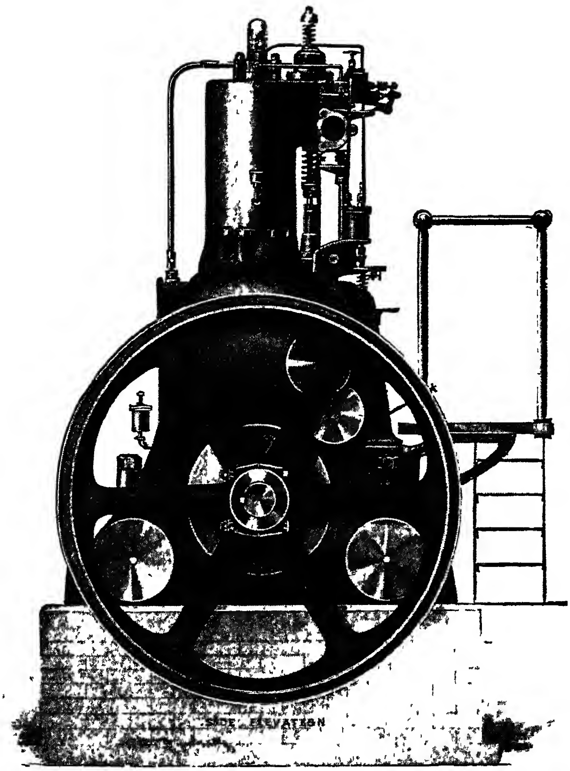


Fig. 394.—First American type, Diesel motor, 30 horse-power

Fourth, that a considerable surplus of air be present.

It will be seen from these conditions that a motor to meet them, although operating upon the so-called "four-cycle" principle, must differ essentially from engines of the Otto type, and it was to realize these conditions that the Diesel motor was designed.

In general construction it resembles the design of a vertical

steam-engine, except that all parts are built to stand the high pressure employed.

In the Diesel engine, compression is entirely independent of the quality of the fuel, for the simple reason that no fuel is introduced until it is wanted to ignite. Pure air alone is compressed, and therefore the intensity of compression is limited only by two factors—the ability of the mechanical construction to withstand the stresses, and the thermal possibilities involved. The high compression produces a temperature sufficient to cause ignition of the fuel, and this ignition takes place as soon as the fuel is introduced to the heated atmosphere in which it burns.

The working cycle is as follows:

On one down-stroke the main cylinder is completely filled with pure air, the next up-stroke compresses this to about thirty-five atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down-stroke the fuel-valve opens, and the petroleum, atomized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by the air in the starting-tank, which is kept by the small air-pump at a pressure some five or ten atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel-charge, which it atomizes as described. When the motor is running at full load, a very small quantity of injected air suffices, and the pressure in the air-tank steadily rises. At half load, with less fuel injected, more air passes in. For this reason, the starting-tank is made large enough to equalize these differences, and a small safety-valve is provided on the air-pump.

The petroleum is pumped into the fuel-valve casing by a small oil-pump bolted to the base-plate. This pump is arranged to pump a fixed maximum quantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply-tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel-valve casing. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of

petroleum to enter the working cylinder at each motor-stroke, the combustion is always complete. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel-valve casing. The valve-gear consists of a series

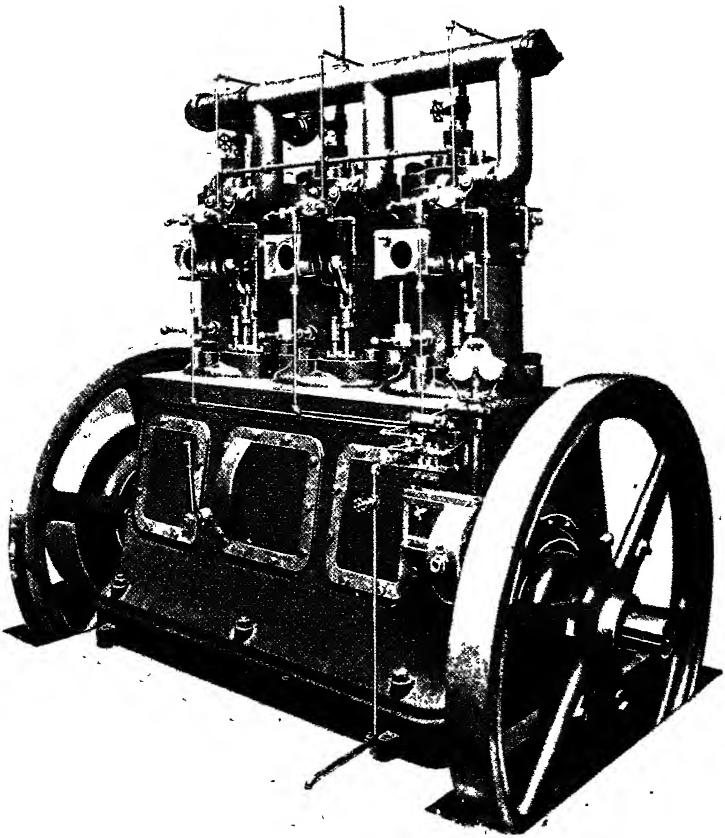


Fig. 395.—Three-cylinder Diesel motor, 225 horse-power.

of cams placed on a shaft journaled on brackets cast on the cylinder.

The highest efficiency indicated has been found to be thirty-seven per cent. at full load and forty-one per cent. at half load, with a brake efficiency at full load of twenty-seven per cent. and at half load nineteen per cent. These high efficiencies are probably

due to perfect combustion under high pressure, which is an essential feature of this motor.

As a machine, the Diesel engine may be fully as frictionless as a steam-engine, and recent tests of a Diesel engine have shown that this is the case. It is also found that an indicated horse-power hour can be got for about 0.32 pound of crude oil with a calorific capacity of about 19,000 B. T. U., and this points to a very efficient

FIG 396.—The crude-oil generator.

utilization of the heat-value of the fuel. This high efficiency is a result due largely to the high compression which is possible only with the Diesel system of fuel admission. It is also partly due to diminished friction and diminished jacket losses.

The future improvement of internal-combustion engines lies so much along the lines followed by Diesel that this motor may be studied to good advantage, for its system of compression removes

the most serious limitations of the ordinary motor, and in weight of combustible per unit of energy output its record is far ahead of any other motor.

The offices of the Diesel Motor Company of America are at No. 11 Broadway, New York City.

In Fig. 396, and following, we illustrate one of the later devices for generating the cheapest of power fuels yet obtained from fluids

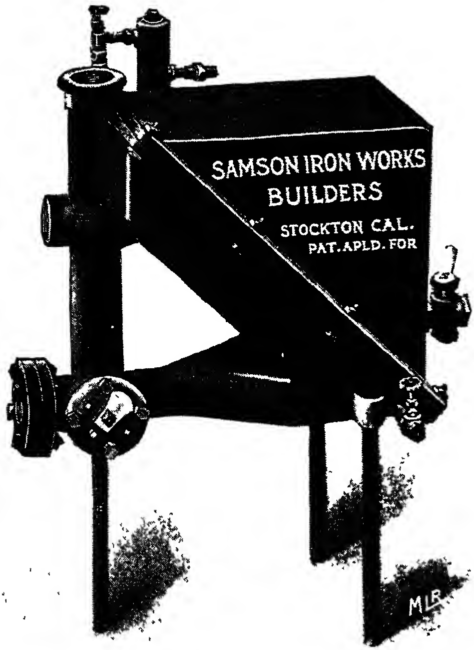


Fig. 397.—Outside view of generator.

or their vapors. Crude petroleum has become directly subservient to the requirement for power-fuel in explosive motors by an evaporative process that utilizes all its available properties and at the same time allows the waste tar products to be discharged, and also of the thorough cleaning of the evaporating surface when required. The generator consists of a chamber of two compartments separated diagonally by a partition on which projects a series of ribs that causes the oil to flow in a zig-zag course down the surface heated by the exhaust through the chamber beneatn.

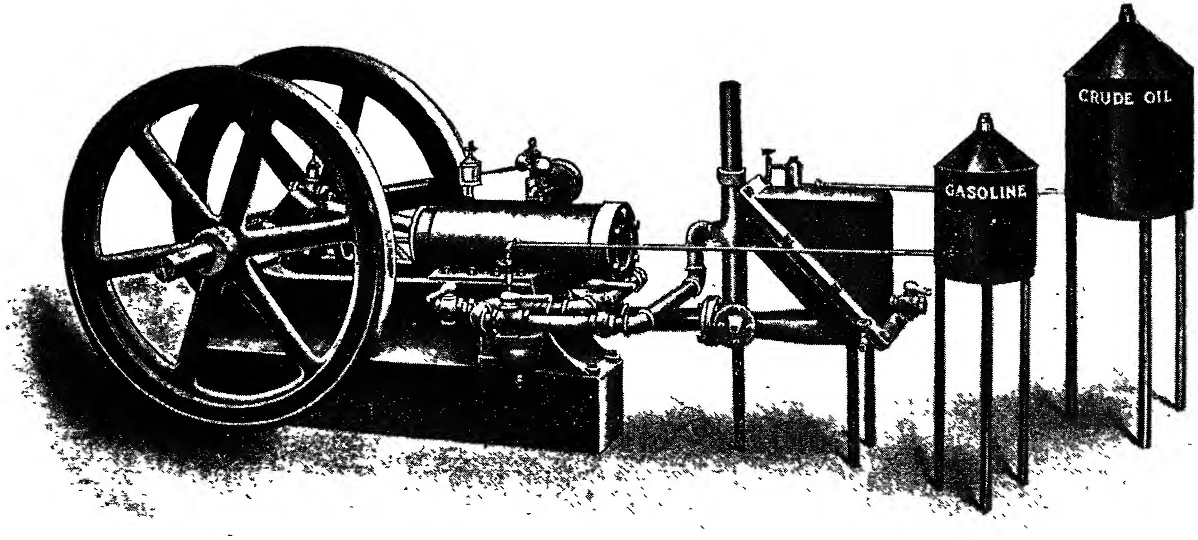


FIG 398.—Crude-oil engine and generator of the Samson Iron Works, Stockton, Cal.

The crude oil is fed at the top, as shown in the cuts; the vapor is drawn to the motor through the pipe and small chamber around the exhaust-pipe as shown. A three-way cock regulates the quantity of the exhaust required for evaporative effect in the generator.

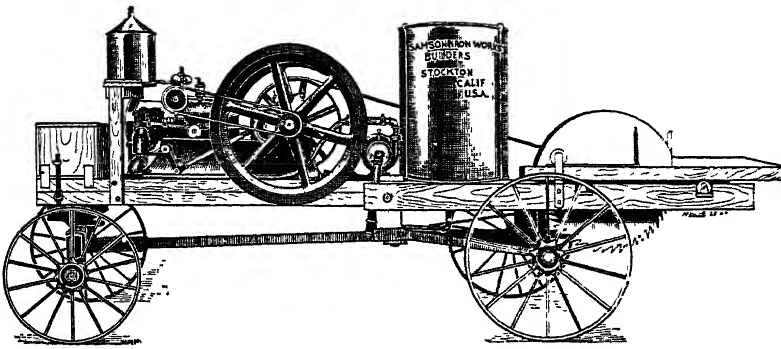


Fig. 399 —Portable oil-motor sawing-rig.

A small injection of gasoline into the air-pipe at the side of the cylinder is used for starting. When the generator is warmed up the crude oil is turned on. The governor regulates the mixture-charge.

This type of oil-gas generator is made by the Samson Iron Works, Stockton, Cal., and applied to their stationary and portable engines.

Traction engines for logging, road work, and portable wheel rigs for power for all kinds of agricultural work are largely in use in the Western States.

The Best Mfg. Co., San Leandro, Cal., also make a crude-oil converter for their oil-motors, for logging, road, and agricultural work.

CHAPTER XXIV

PRODUCER-GAS AND ITS PRODUCTION

THE theory of the formation of this gas is that, by limiting the amount of air admitted to the fire, complete combustion of the coal is not permitted and the supply of oxygen being insufficient, carbon monoxide, CO, is formed instead of carbon dioxide, CO_2, while the steam formed in the vaporizer is led back under the grate and breaks up on striking the incandescent fuel, giving free hydrogen and carbon monoxide, the carbon monoxide and the hydrogen forming the power-gas for the engine.

The average gas, with a good grade of anthracite, should have a heat value of 130 to 140 British thermal units per cubic foot, and the constituents by volume as follows:

Carbon dioxide, CO_2	6 %
Carbon monoxide, CO	24 %
Hydrogen, H	15 %
Nitrogen, N	55 %
Hydrocarbon, CH_4	trace
Oxygen, O	trace

The actual combustion in the producer forms, at the grate, carbon dioxide, which on passing up through the glowing coal above the grate is robbed of one atom of oxygen to supply the coal above, which is getting insufficient air, and becomes in great part CO. The steam, H_2O, which is admitted under the grate, on encountering the glowing mass of coal is broken up into hydrogen and oxygen. The hydrogen passes through the producer as a free gas, while the oxygen unites with the coal to form CO.

Injection of steam under the grate serves four purposes:

First. It gives the hydrogen for the actual power-gas.

Second. It furnishes oxygen to the fire on breaking up and

gives greater freedom from clinkers due to more complete combustion.

Third. It keeps the grate cool and prevents the burning out of grate-bars.

Fourth. It is made by the heat of the gas passing from the generator, utilizing this heat which would otherwise be wasted, and bringing the gas to more nearly the temperature required at the engine, where it must be cool.

Should the apparatus be of faulty design and more steam be admitted than the fire can break up, the effect will be a deadening of the fire and the diminution of the gas formed and in the end a complete shutting down. On the other hand, if an insufficient amount of steam is provided, the grates will burn out rapidly and the gas, through a lack of hydrogen, will be lacking in power.

When anthracite is used, the amount of water transformed should be from 0.8 to 1.2 the weight of the coal.

In the cheaper forms of apparatus the cleaner is often omitted, but an examination of the pipes on such a plant after a month's use will conclusively prove its necessity. Where water is an important factor, the scrubber may be run hot and less water used, but it will be done at the expense of a cleaner which will be forced to remove a greater percentage of dust carried through to it by the uncondensed vapor, so that the sawdust and shavings in the cleaner will require more frequent renewal. Wherever necessary a cooling system can be installed and the water reused after slight filtration.

As an example of the efficiency with which the gas is cleaned and dried, an instance may be cited of an installation of Julius Pintsch, at Heusy, in Belgium, which was run for an entire year without any cleaning of either engine or gas-apparatus; the deposit of foreign matter found at the end of the year was inconsequential.

The superiority of the suction system over the pressure type of gas-producers has been conclusively demonstrated. Originally many objections were raised to the suction type, and the idea of having the engine draw in its charge of gas, thereby making the draft for the fire, was considered impractical. The point was raised that the gas, being at less than atmospheric pressure, would interfere with the satisfactory working of the engine. If it were impossible to regulate the admission of the air with the pressure of the gas this

objection would hold true, but this is taken care of by providing a separate air-inlet on the engine which allows the formation of a suitable mixture in all cases.

Suction gas-plants are simpler and require less room than pressure plants. They are more economical of fuel and require less attention. They require no separate steam-boilers or large gas-holders and there is no chance for gas to escape into any of the rooms of the building as the whole apparatus is always under slightly less than atmospheric pressure, and any leakage would be of air into the apparatus instead of gas out. A leakage sufficient to bring about a stoppage would have to be very large and could not occur except through some extraordinary accident.

In the pressure type the air necessary to maintain the fire in the gas-generator enters the bed of fuel under pressure, caused by a steam-jet, blower, fan or similar means. Hence the gas passes through the apparatus and reaches the engine under a pressure of two or three inches of water.

In the suction type the air required for generating gas is drawn through the bed of fuel and the resulting gas is then drawn through the cooling and cleansing apparatus by the sucking action or partial vacuum created by the engine-piston.

The pressure system has the advantage of being able to use a greater variety and an inferior quality of fuel than the suction type.

Anthracite or bituminous coals, lignite, wood, peat, tan-bark, coke, and charcoal may be successfully gassified in the pressure-type producer. It can also work more satisfactorily when supplying gas to a number of engines from a central producer plant.

In the suction type the character and heat value of the generated gas are essentially the same as from a pressure type of plant. It is of the first importance that good coal be selected, if undue care and interrupted operation are to be avoided. It is best also to install an apparatus of ample capacity for the work desired. The overrated power of these installations has oftentimes caused needless annoyance and expense, besides condemning an apparatus of much merit when intelligently proportioned and rated.

To date, the use of bituminous coal is confined to large units. In order to successfully operate a gas-engine, the tar must be removed, which necessitates either an elaborate system of scrubbers

and cleaners, or the combustion of the tar in the producer itself. Working on the latter principle, Julius Pintsch has in operation plants for both lignite and bituminous coal, a plant of 400 horse-power working admirably on the latter fuel with the very low consumption of ten ounces per brake horse-power hour. With bituminous coal at $3.00 a ton, this brings the cost per horse-power hour down to $\frac{3}{32}$-cent per horse-power hour, which, barring water-power and natural gas, may be said to be the cheapest form of power yet known.

COKE-OVEN GAS

The coke industry affords an important field for gas-power. Coke by itself represents about 75 per cent. of the best value of the coal coked. The remaining 25 per cent. in the case of the ordinary bee-hive oven is discharged into the atmosphere in the form of products of combustion. The gaseous distillate is practically the same as ordinary retort coal-gas and as such forms a most excellent fuel for power purposes.

In the process of coking coal in closed retorts or ovens, the gas obtained is obviously similar to the coal-gas manufactured for illuminating purposes, and contains an average of 39 per cent. of hydrogen, 45 per cent. of hydrocarbons, 5 per cent. of carbon monoxide, and 3 per cent. of carbon dioxides.

For this gas, the gross heat value is 679 British thermal units per cubic foot and the available heat value 560 thermal units. The gas leaves the retorts at a high temperature and carrying a considerable burden of impurities, must be cooled and purified before it is fit for use in an engine-cylinder. Its high hydrogen contents makes it somewhat sensitive and violent; but with reasonably careful adjustment and operation it constitutes a good fuel for use in a gas-engine.

In coking one ton of average coking-coal in a retort there are generated from 8,000 to 10,000 cubic feet of gas, carrying from 60 to 100 pounds of tar and 10 to 25 pounds of ammonium sulphate. The tar and sulphate must be extracted and are marketable—their sale value more than covering the cost of their extraction; but generally the gas carries an excess of sulphur and always some dust, and the amount of these must be reduced to a minimum.

Of the total volume of gas only about one-half is required for carrying on the coking process; a balance of 4,000 to 5,000 cubic feet remains available for other purposes, such as illumination or power-generation. In other words, in the coking of one ton of coal there become available, and are only too frequently wasted, about 2,500,000 thermal units, sufficient to develop in gas-engines at least 205 effective horse-power hours. Thus for every 11 pounds of coal coked per hour, one effective horse-power is available as a by-product.

In the Connellsville district about 300,000 tons of coal are coked per week. The surplus gas from this coal would develop 366,000 effective horse-power continuously.

The use of coke-oven gas is one of the results of the perfection of the by-product coke-oven, although the primary object of this form of oven was perhaps as much for the recovery of tar and ammonia as for the waste gases. About half of the gases are, however, used as fuel for heating the ovens themselves for the distillation of the coal charges and the recovery of the gas for this purpose was undoubtedly the primary object sought.

But since only a portion of the gases voided are necessary for heating the ovens, the remainder are available for other uses, and while they have been used as fuel in boilers, it has been found that for the production of power a most efficient use has been to burn them, after purification, in the cylinder of a gas-engine.

In showing the adaptability of the waste gases of coke-ovens in gas-engines, and also the magnitude of the power available, it is preferable to sketch briefly the method by which they are generated, and so exhibit their qualities and qualifications for this work.

The possibility of utilizing this source of power may be said to be due to the development to perfection of the by-product coke-oven, though perhaps the contemporaneous development of the gas-engine itself should be counted as an equal factor. It may not be known to all that the operation of coking coal consists simply in heating it, out of the presence of the atmosphere, so that the volatile matter is distilled off, leaving almost pure carbon or coke as the residual product. The coal is delivered to each oven from a travelling larry, which runs over the top, through spouts, thus delivering the

fuel charge comparatively level on top and nearly filling the oven. The heat is supplied to the ovens by the combustion of gas beneath them, the products of combustion passing up through flues in the brick work between each oven. The air used in burning the gas is brought from the outside through a regenerator placed under the ovens, whereby it becomes heated to a high temperature, thus making the temperature of combustion correspondingly higher. The burned gas, after passing through the flues between the ovens, is led through the regenerator. The valve arrangement allows of a transposition of air and burned gas in the regenerators, so that one is being heated by burned gas while the other is giving up its heat to the air used in the combustion.

Coke-oven gas is largely in use in England, Germany, and Belgium, and although on limited trials only in the United States, its future extension is apparent, and pipe-line extensions may build up large industries within reasonable distances from the coke-producing centres.

BLAST-FURNACE GAS

The gases from blast-furnaces, heretofore used under boilers for generating steam for power to drive the blowing-engines of the furnaces, is now coming into use for a more direct application of its power by its use in the cylinders of the blowing-engines.

Its limitation to the iron-making districts bars it from general use, but the surplus power above the requirement of the furnace, when used in a gas-engine for the furnace-blast, hot stoves, etc., makes it an available means of profit for distribution to a neighborhood. The approximate analysis of blast-furnace gas is as follows:

Hydrogen, H	5.2 %
Carbon monoxide, CO	26.8 %
Marsh gas, CH_4	1.6 %
Carbon dioxide, CO_2	8.2 %
Oxygen, O	.2 %
Nitrogen, N	58.0 %
	100.0

Heating value 106 British thermal units, and from 80 to 120

cubic feet is required mixed with an equal quantity of air per horse-power per hour.

Blast-furnace gas is found by experience to make an excellent power-gas, as it is not "snappy," therefore permitting of comparatively high compression and consequently high efficiency. The difficulties in cleaning have apparently been overcome and several American engine-builders are prepared to meet the demand for heavy-duty engines of several thousand horse-power capacity. Every iron and steel works operating a blast-furnace establishment should thus become a producer of energy for its own and outside consumption, instead of an augmenter of the smoke nuisance.

It is now generally conceded that blast-furnace gas must be cleaned before use in the gas-engines; if for no other reason than that the cleaning process at the same time reduces its temperature and thus increases its density, thereby increasing the power available from a cylinder of given dimensions. Whether cleaned by transmission through great length of pipe at low velocity, or by contact with sprays or surfaces of water, the temperature is lowered. Cooling and cleaning by the dry or transmission method is not satisfactory, and becomes very costly if a temperature below 120° F. is desired. Nor do conditions of velocity, satisfactory for cooling, permit the settling of the dust, and the finest particles, when dry, require practically absolute rest, which is, of course, impossible. Water cooling and washing is now generally employed.

For the gas delivered at the top of a blast-furnace, consisting of the products of combustion and partial combustion of coke, and the decomposed moisture and volatile contents of the charge, the average volumetric composition is:

Hydrogen	2.25 %
Hydrocarbons	.25 %
Carbon monoxide	24.5 %
Carbon dioxide	.12 %
Nitrogen	62. %

Gross heat for this gas is 92.5 British thermal units per cubic foot and available heat 86 heat units.

This gas leaves the furnace top at a temperature of about 400° F. and carrying a considerable burden of dust and moisture. It

must be cooled, cleaned, and dried before it is in a condition fit for use in an engine cylinder. The heat value of blast-furnace gas lies chiefly in its carbon monoxide, the proportion of hydrogen being very low; the gas is therefore neither sensitive nor violent, will safely permit a high compression, and as a result its ignition is sure and its efficiency high in spite of its low heat value.

For each ton pig-iron output, the average blast-furnace delivers about 10,500 pounds of gas at its top. In other words, the gas delivered by a blast-furnace weighs 4.7 times as much as the pig-iron it produces. The volume of such gas at 62° Fah. and 30 inches of mercury, equivalent to a weight of 10,500 pounds, is 131,000 cubic feet. Thus, per ton of pig-iron produced, there are delivered by the furnace 11,266,000 net thermal units.

A portion of this gas is utilized to heat the blast for the furnace to a temperature of about 1,200° Fah., but a surplus of 76,000 to 77,000 cubic feet, or, say, 6,580,000 heat units per ton of pig may be safely figured upon.

As has been stated, the gas, as it leaves the blast-furnace top, is hot, dirty, and wet, and must be cooled, cleaned, and dried. A typical mode of procedure is to pass the entire volume of gas through a dust-catcher, the area of which is proportioned so that the gas travels at a low velocity. In this dust-catcher the major portion of the heavy dust settles out, and the gas temperature is reduced by radiation. As a rule, the gas passes directly from here to the stoves and boilers. If the gas-mains are long and of ample diameter, a further considerable quantity of dust settles out in them, and where water is scarce and space available, a multiplication of dry-dust catchers or long, large mains with dust-pockets affords an efficient means at low operating cost for all but the final drying and cleaning.

But where an ample supply of cold water can be obtained, the cooling and cleaning of the gas becomes simpler and all the gas—whether for stoves, boilers, or gas-engines—should be washed by passing either through vertical tanks or horizontal pipes against fine sprays of water. The gas for gas-engines must be still further cleaned and dried, and various means can be employed for this purpose: coke-scrubbers with steam-jets, lattice-work with water-curtains, or centrifugals with water-injection, these to be followed by

filters consisting of layers of excelsior or sawdust, or followed by water-separators.

Provision of a gas-holder is always desirable, but its capacity per gas-engine horse-power may be varied to suit the blast-furnace plant—the greater the number of furnaces, the smaller may be the gas-holder. A satisfactory gas-cleaning installation in a plant whose space will not permit more than a fractional cooling by direct radiation, consists of vertical tanks set in water-seal catch-basins followed by centrifugals with water-injection.

PRODUCER-GAS FOR MARINE PROPULSION

Experiments are in progress for utilizing producer-gas for launch, yacht, and ship service, not only for economy over fluid fuels now in use, but for safety from the occasional disasters due to the use of the highly volatile fluids. Trials of marine engines driven by producer-gas now being made in Germany by Mr. Capitaine, and in England by Thornicroft and Company and Beardmore and Company, which may make a further and more extended use of the explosive motor for marine propulsion.

It is claimed that the additional weight of engine, producer-plant, and coal will be but slightly increased beyond the present equipment of marine motors of the explosive type and far less than for steam-driven motors.

PRODUCER-GAS GENERATORS

This gas, like its congeners—water-gas, Dowson gas, suction or aspirated gas, and Mond gas—is made by distilling by heat and steam or air, bituminous or anthracite coal in a closed furnace, using the heat generated by their partial combustion for producing the chemical reaction resulting in a permanent gas of varying constituents due to the different methods of operating the generating furnaces.

In Fig. 400 is illustrated a producer-gas generator in which A is a swing or lift-door for feeding coke, anthracite, or bituminous coal to the furnace B, and for blowing up. C, fire-brick walls of the furnace. E, air-inlet for heating the furnace of the generator. F and G, gas blow-off pipe, interchangeable to reverse the gas-blow. J,

valve that automatically closes when A is opened. L, L, steam-pipes for alternating the steam-blow. H, superheating coil for heating the steam by the hot gases passing to the scrubber M. N, sprinkler. K, wheel and drum for simultaneously opening and closing the valves, J and G, and the blast-door A. The initial firing produces CO_2 with air alone, and an addition of hydrogen when steam is blown alternating with air. The air-blast raises the heat of the furnace to a high temperature; when the air is shut off and steam turned into the furnace, it is forced into contact with the surface of the hot coal

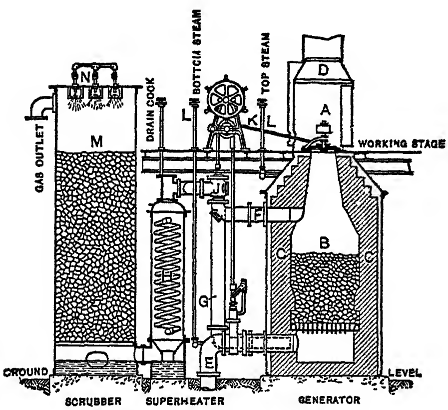


FIG. 400.—Gas producer.

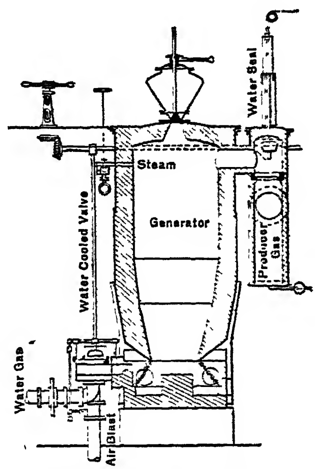


FIG. 401.—Gas generator.

and becomes dissociated, the oxygen uniting with the carbon, forming carbonic monoxide CO, setting hydrogen free. This product is technically termed water-gas. While the non-use of steam or the mixed use of steam and air in the after-blow produces the various grades of gases and their respective heat values, all producer-gases, but termed technically water-gas, semi water-gas, Mond gas, and suction or inspirator-gas, are later detailed as to analysis and heat value. Fig. 401 illustrates a simple gas-generator of the Lowe type, an iron cylinder lined with fire-brick. Air is blown in at the bottom for heating the coal or coke. Then steam is blown in at the top, passing through the hot fuel, and discharged at the bottom as water-gas. Fuel is fed through the hopper at the top. By reversing the blowing by steam and air, producer-gas

is made and discharged through the side pipe at the right. This simple generator is only suitable for anthracite or coke-fuel.

In Fig. 402 is illustrated a gas and steam generator of Belgian design. A magazine-furnace with a double-valve hopper for charging the magazine. The steam-generator consists of a number of drop-tubes closed at the bottom, each with a central water-feed tube of smaller size. The drop-tubes are screwed into the bottom plate of the steam chamber, which has a partition to separate the

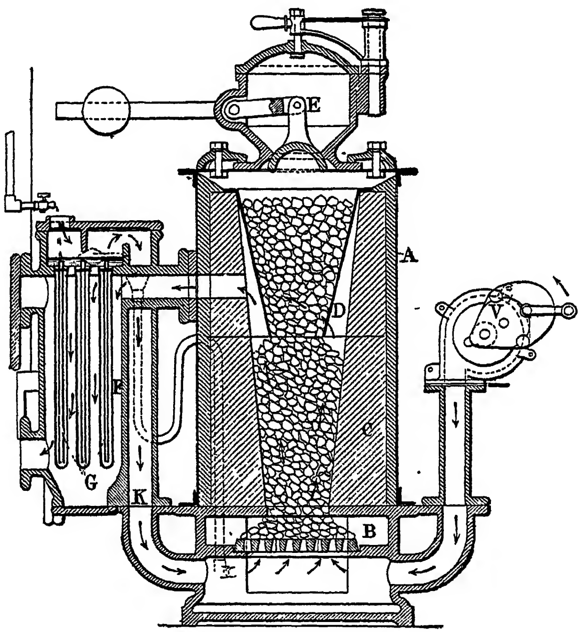


Fig 402.—Gas and steam generator.

water-inlet from the steam compartment, from which the steam is drawn through the small pipe to the ash-pit beneath the grate. The blower at the right is for starting the fire. The air is drawn in for continuing the combustion through the pipe K, by the suction of the motor.

Fig. 403 represents a very complete producer-gas generator of German type, in which steam is generated in a double-shell boiler at the left in the cut, superheated in a coil over the fire, and then passed through the combined air and steam inlet to the converter,

the incoming air being heated in the jacket of the outgoing gas-pipe. The blower is not shown. To the right of the converter is a tar-box and waste-siphon.

In addition to the usual scrubber, a lime-purifier is used to eliminate any sulphurous gases passing the scrubber.

In Fig. 404 is illustrated the German producer-gas plant of Julius Pintsch.

This producer was simple in construction and operation, required little attention, and gave a brake horse-power hour in small units on one pound of Belgium anthracite. Four years' practical experi-

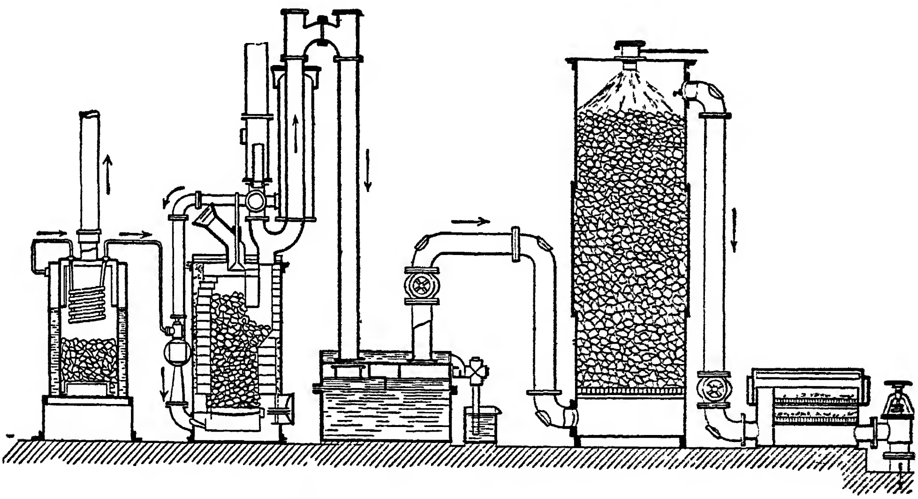


FIG. 403.—Purified producer-gas plant.

ence with this plant brought many improvements and the construction of the present Pintsch suction gas-plant is as follows: In Fig. 404, A is a blower, furnishing draught for starting the fire and raising the heat in the generator to the proper temperature for the production of gas; B, the generator, equipped with a grate on which the coal is burned, a hopper H, which allows charging during operation, a window-valve for inspection of the fire, and fire-doors for poking down; C is a vaporizer fitted with a small tubular boiler for the generation of steam, and a relief-pipe or chimney for use when the engine is not running; D, a scrubber consisting of a coke-tower with a water-spray for washing the gas; E, a cleaner containing wooden trays

covered with wood shavings or sawdust through which the gas is filtered, giving up the last of its dirt and dust; F, a governor or pressure-equalizer for maintaining a steady pressure throughout the apparatus.

To operate the plant, a fire is lighted in the generator and a small amount of coal added, the blower being run until the fire is burning strongly with the relief-valve R open. After ten to fifteen minutes blowing, the fire is sufficiently hot to give off gas; the relief-valve is then closed and the gas allowed to pass through the apparatus, the blower being kept running at slower speed until the gas burns freely at a test-cock beside the engine. The engine is then started, the

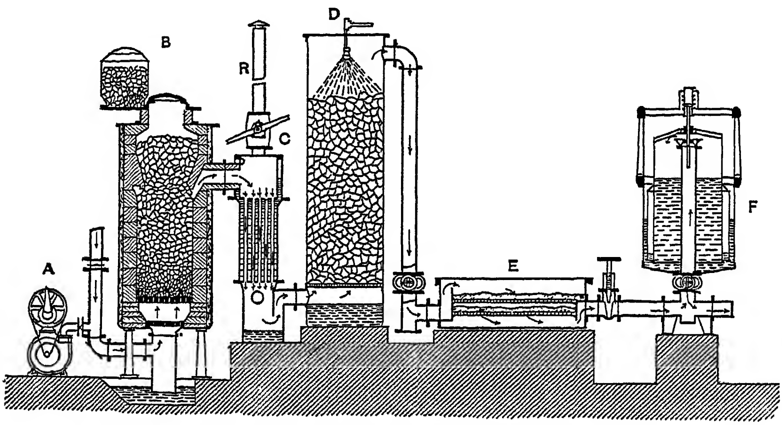


FIG. 404.—Pintsch producer-gas plant.

blower stopped, and the formation of gas becomes automatic; the suction-stroke of the engine furnishes the draft through the fire.

In ordinary practice, the fire is left burning overnight with limited draft and only a few minutes' blowing is required to brighten up the fire in the morning. The generator should be kept full of coal and the fire kept clean and bright. Since the apparatus is always under a slight vacuum, the fire-doors can be opened at any time for cleaning out the fire.

The vaporizer is built in three sections, the upper being simply a chamber connected with the relief-pipe or chimney; the middle, a small tubular boiler, and the base section acting as a cleaning-pot and water-seal when the engine is not running. By the passage of

the hot gases coming from the generator through the flues of the boiler, the gas is cooled and steam is generated which is passed back under the grate. The cleaning-pot or bottom section collects the heaviest dust and dirt coming over with the gas. By the admission of water to the cleaning-pot on shutting down, the rest of the apparatus is water-sealed and the gas therein kept intact for starting up again.

The scrubber should never feel more than warm to the hand, otherwise steam will pass through it to the apparatus beyond, carrying with it a considerably greater percentage of dust, and the gas will not be cool when it reaches the engine. The gas must reach the engine cool or the charge taken in will be a charge of expanded and rarefied gas and will not carry sufficient energy.

In the cleaner, the gas gives up the last of its dust and moisture and emerges cool, clean, and dry.

The apparent simplicity of the suction gas-producer has led to the introduction of plants in which the chemical and scientific sides of the problem have been entirely disregarded. Cheapness of first cost has been sought rather than economy of operation, the arrangements for cleaning the gas being in almost every case insufficient, so that the whole installation requires frequent cleaning. The dirt thus allowed to pass through with the gas fouls the valves and cylinder of the engine, causing a leaky piston and rapid deterioration of the moving parts.

In Fig. 405 is illustrated a suction gas-plant of the Crossley type.

Besides producers of the pressure type, for use with either anthracite or bituminous coal, Messrs. Crossley make a special feature of their suction-gas producer-plant, which consists of the producer proper, coke-scrubbers, and an expansion-box. The construction of the principal parts is shown in the cross section, which is largely self-explanatory; the engine draws air and steam through the fuel in the producer, generating the gas, which passes through the scrubbers on its way to the engine. The steam is raised by the waste heat of the producer from water surrounding the bell of the feeding hopper, and is superheated before entering the furnace. The hopper holds sufficient fuel to last for four hours without attention, the operation of the plant being automatic. The notable features of this producer plant is the water-jacketed magazine-bell which acts as the steam-

generator, air and steam mixing chamber at the top of the generator, and the double-chambered scrubber, in which the gas and water flow in one direction, depositing the ash, tar, and dust in the hydraulic box, while the contrary currents in the compartment further

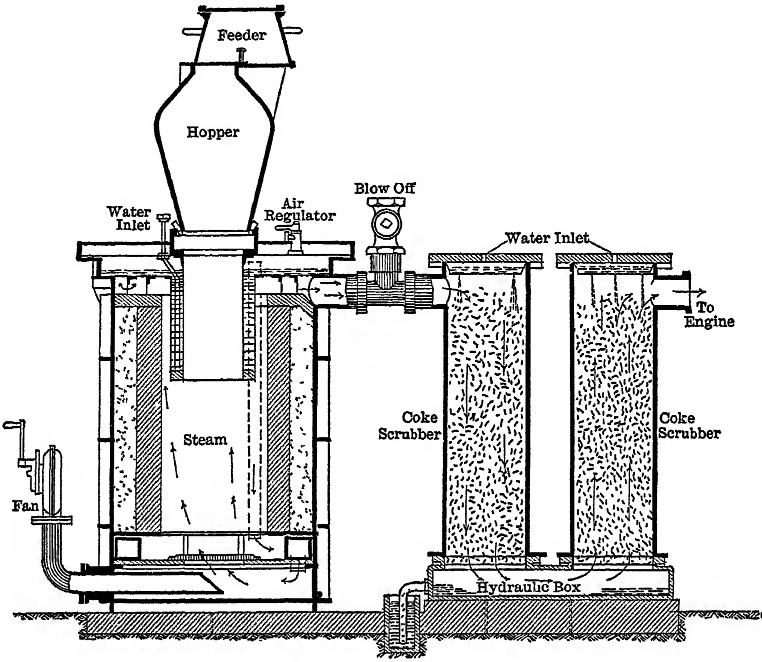


FIG. 405.—Crossley suction gas-producer.

clear the gas from sulphurous gas and ammonia. The friction of the gas is also partially eliminated by passing with the water current through one-half of the length of an equal single scrubber, besides being a convenience in compactness of the plant.

It is claimed that there is considerable economy of fuel with the statement that the consumption of anthracite at full load is from 0.65 to 0.85 pound per brake horse-power hour, and of water 1 gallon for all purposes. The plant is made for outputs up to 300 brake horse-power, the largest size occupying a space of 21 feet 6 inches by 15 feet by 19 feet high.

In Fig. 406 is illustrated the Mond gas-generator, which is briefly described as follows:

The cheapest bituminous slack obtainable is mechanically deposited in hoppers above the producers. From this it is discharged into the producer-bell, where the heating of the slack takes place, and the products of distillation pass down into the hot zone of fuel before joining the bulk of the gas leaving the producer. The hot zone destroys the tar and converts it into a fixed gas, and prepares the slack for descent into the body of the producer, where it is acted upon by an air-blast which has been saturated with moisture and water superheated before contact with the fuel. The hot gas and undecomposed steam leaving the producer pass first through a tubular regenerator in the opposite direction to the incoming blast. An exchange of heat takes place, and the blast is still further heated by passing down the annular space between the two shells

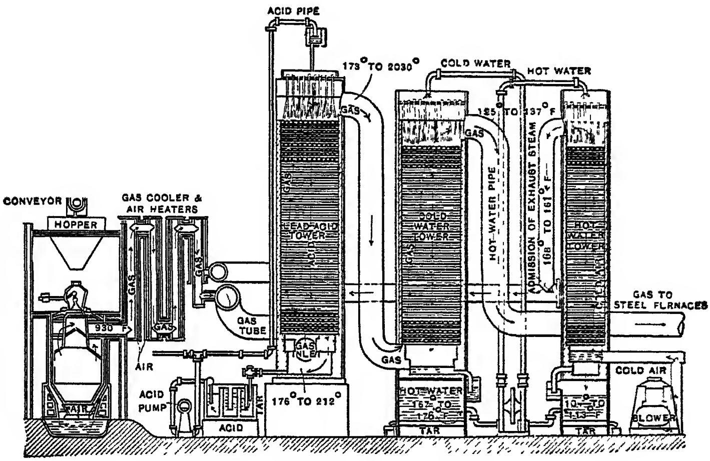


Fig. 406.—The Mond gas-generator.

of the producer on its way to the fire-grate; then the hot products from the producer are further passed through a "washer," which is a large, rectangular, wrought-iron chamber with side-lutes; and here they meet a water-spray thrown up by revolving dashers, which have blades skimming up the surface of the water contained in the washer. The intimate contact thus secured causes the steam and gas to be cooled down to about 194° Fah., and by the formation of more steam tending to saturate the gas with water-

vapor at this temperature, then passing upward through a lead-lined tower, filled with tile to present a large surface, the producer-gas meets a downward flow of acid liquor, circulated by pumps, containing sulphate of ammonia with about four per cent. excess of free sulphuric acid.

Combination of the ammonia of the gas with the free acid takes place, giving still more sulphate of ammonia, so that, to make the process continuous, some sulphate liquor is constantly withdrawn from circulation and evaporated to yield solid sulphate of ammonia, and some free acid is constantly added to the liquor circulating

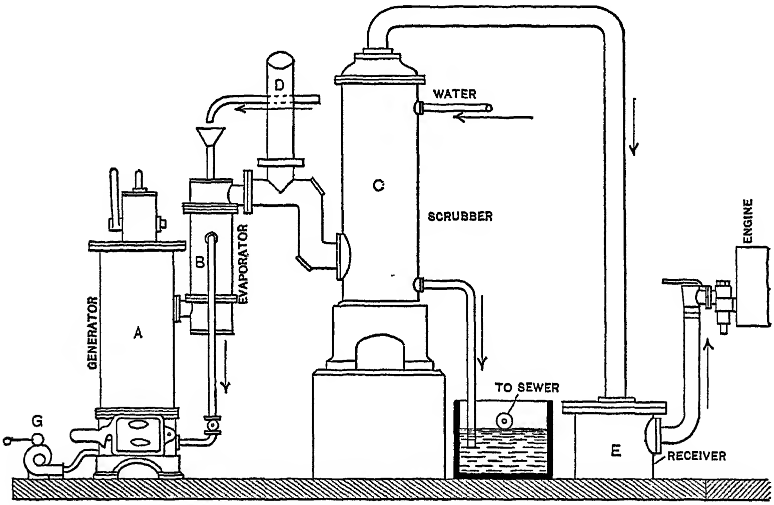


Fig. 407.—Suction or aspirator gas-plant.

through the tower. The gas, being now freed of its ammonia, is conducted into a gas-cooling tower, where it meets a downward flow of cold water, thus further cooling and cleaning it before it passes to the various furnaces and gas-engines in which it is used.

Fig. 407 illustrates a suction or aspirator gas-plant and connection with a gas-engine in which A is the generator proper, where the combustion takes place. The gas produced passes into the evaporator B, the interior of which is filled with small vertical tubes through which the hot gases pass while water trickles over their outer surfaces, cooling the gas and at the same time evaporating the

water, which, mingling with the air, also drawn in at the top, is carried into the generator A. The evaporator is provided with an overflow for the water which is not thus evaporated.

From the cooler, or evaporator, the gas passes to the scrubber C, which is simply a shell filled with coke through which the water passes downward against the ascending current of gas, the water being discharged to the sewer from the collecting tank at the bottom, while the gas passes to the receiver E. The coke and the water retain not only the entrained dust, but the ammonia and other chemical impurities of the gas.

The receiver E may be replaced to advantage by a small gas-holder with water-seal and top section suspended by a very elastic spring, to neutralize the jumping action of the engine-piston.

In order to start the generator, the small hand-blower G is employed, by the aid of which sufficient air is introduced to ignite the bed of fuel. The gas at first formed, which is not suitable for use in the engine, is allowed to escape to the atmosphere through the escape-pipe D. Some fifteen or twenty minutes after the generator has been ignited, the pipe D may be closed and the engine started. The aspiration by the engine itself commences, little by little the normal condition is established, and in from one-quarter to one-half an hour the gas becomes sufficiently rich to take care of the motor under full load.

In Fig. 408 we illustrate the suction gas-plant as built by Mr. Oscar Nagel, No. 90 Wall Street, New York City.

The suction gas producer-plant consists of a producer, an evaporator, an overflow water-pot, a scrubber, and an equalizer.

The producer is lined with fire-bricks. By the sucking action of the engine a mixture of air and steam is drawn through the burning fuel, whereby the producer-gas is generated.

The producer is provided with a hopper through which fuel can be filled into the producer without interfering with the working of the engine. The cleaning of the grate may be performed during the regular work.

The gas leaving the producer heats up the evaporator and causes a formation of steam which goes under the grate together with the necessary amount of air. From the producer the gas goes through the scrubber, in which it is cooled and purified from the

dust and tar. From the scrubber it goes through a small equalizer to the engine.

Before starting the engine the fuel in the producer has to be heated up by means of a small hand-blower *a*, attached to same, until the fuel is burning well. For this about ten minutes are required. When this point is reached the hand-blower is stopped and the engine started in the usual way.

The engine then draws, by its own sucking action, the necessary amount of air and is producing its own power-gas. The air is entering at *c* and goes through the evaporator *b*. Here it is saturated with steam and the mixture of air and steam passes through pipe *d* under the grate of the producer, through the fuel, and then through pipe *e* to the scrubber; from here through pipe e_1 to the equalizing tank *f*, which is directly connected with the engine. *k* is the overflow and tar-box.

The gas-making process continues as long as the engine is running, but as soon as the engine is stopped the gas-making is also stopped.

The cut shows a sectional elevation of a 25 horse-power plant. The plants up to this size are provided with a sufficiently large fuel-hopper so as to contain fuel for the working-day and to avoid the necessity of recharging the fuel during the working-hours. The sizes above 25 horse-power are provided with a bell-hopper, and the sizes about 75 horse-power have, instead of a water-jacket evaporator, an independent evaporator. These producer-gas plants can be used equally well on board of boats in connection with producer-gas marine engines.

Anthracite, charcoal, or coke can be used for generating gas in the suction gas-producer. It will take, according to the ash content, 1 to 1¼ pounds of anthracite or charcoal, or 1¼ to 1⅓ pounds of coke for developing 1 horse-power per hour. With anthracite (pea) at $5.00 per ton, 1 horse-power for 24 hours will cost from 6 to 8 cents. This is about one-sixth the cost of illuminating gas-power (at a price of 75 cents per 1,000 cubic feet of illuminating gas) or one-eighth the cost of gasoline (at a price of 16 cents per gallon).

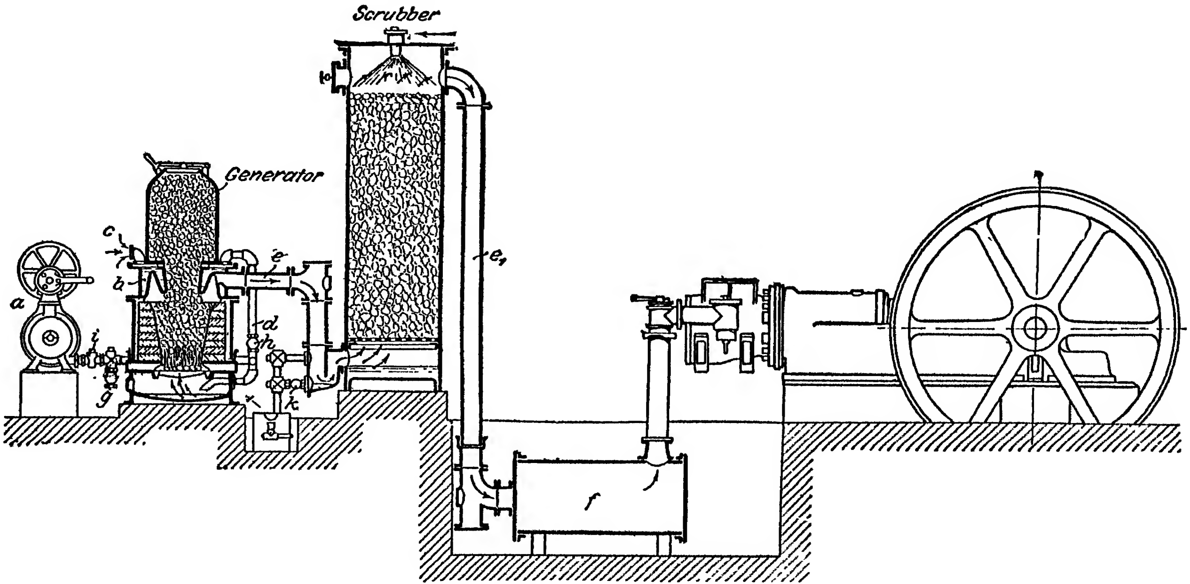


FIG. 408.—Suction gas producer-plant, built by Mr. Oscar Nagel, No. 90 Wall St., New York City, in units from 5 to 300 horse-power.

SUCTION OR ASPIRATOR-GAS

In the above-described gas-producer the boiler and gas-holder, two troublesome adjuncts, are dispensed with and their cost, care, and room made a saving clause in the generation of power. In this apparatus the gas is produced directly by the suction or aspiration of the motor and in such quantities as required for immediate use.

In the use of this gas, an open fire in the generator, to give the draught of the motor as free from obstruction or friction as possible, is desirable, such as derived from coke or clean anthracite coal.

The average composition of this gas from coke of 13 240 heat units per pound, consists of:

Hydrogen, H	7.0%
Monoxide of carbon, CO	27.6%
Methane or Marsh gas, CH_4	2.0%
Carbonic acid, CO_2	4.8%
Nitrogen, N	58.6%
	100.0

One cubic foot weighs 0.0748 pounds and density 0.93 (air 1) with a heating value of about 135 British thermal units per cubic foot.

The volumes of air and gas in the charging mixture are proportionately as their heat-unit values; so that, practically, with the low combustible value of this gas, but 1.25 parts of air to 1 part gas is required for perfect combustion. This requires a like proportion of the inlet-ports and supply-pipes and their change to these proportions in motors built for illuminating and other high thermal gases and vapors. The size of the motor for a given horse-power is also subject to the heat value of the combustible used for power. Hence a gas-engine of given dimensions, using illuminating gas of 700 heat units per cubic foot and in proportions of 6 air to 1 gas, will represent a power of $\frac{700}{7} = 100$ heat units per cubic foot of the mixture fed to the engine; while with suction-gas of 135 heat units, the power will be represented by the charging mixture,

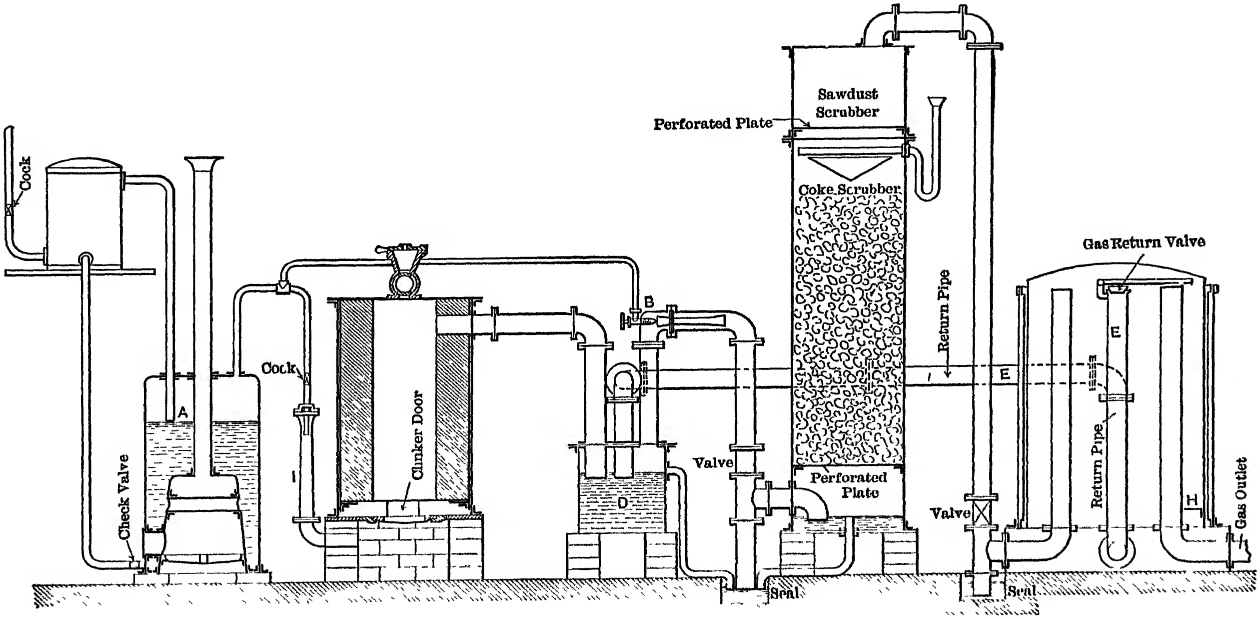


FIG. 409.—The Wile automatic-pressure producer-gas plant.

$1\frac{1}{4}$ air to 1 gas $= \frac{135}{2.25} = 60$ heat units per cubic foot of the mixture fed to the engine. These differences should represent inversely the relative volumes of the cylinders for equal power.

In Fig. 409 we illustrate an automatic-pressure producer-plant as built by the Wile Power Gas Company, Rochester, N. Y.

The automatic producers represent a considerable advance in the producer-gas industry, combining the best features of ordinary suction and pressure producers.

An important feature of the automatic type is that the producer is under suction while the gas is supplied to the engine under a constant pressure of a few inches of water in a small regulating gas-receiver. The producer is fitted with a regulator which automatically controls the amount of gas generated and at the same time ensures a uniform quality of gas which is essential for the steady working of any gas-engine.

This producer uses any class of fuel which is available and makes the gas automatically as it is required. When the demand ceases, the aspirator, instead of drawing air and steam through the fuel-bed and generating new gas, circulates the gas already made. As only the amount of steam and air enter the fire which is necessary for making gas, the fire in the producer has a uniform temperature and only gas of uniform quality is made.

Pressure gas-plants, the main characteristics of which are a steam-boiler and gas-holder, which can also be used for power or heating or both, obtain their draught by means of steam raised to a pressure of about 40 pounds in a small steam-boiler, which is led through an injector placed at I (Fig. 409), and enters the generator mixed with air and making the gas as above described, which then passes through the hydraulic seal-box and the scrubbers to the gas-holder. This position of injector for making gas is very satisfactory when the load is constant, but difficulty is experienced in making gas of uniform quality under varying loads, and to meet this demand an improved pressure-plant has been designed, in which the injector is placed at B (Fig. 409), above the water seal-box D, and a return pipe E comes from the gas-holder to the seal-box D. It will be recognized that with the injector at I gas will constantly be manufactured unless provision is made for cutting off the steam-jet when the gas-holder is full and no further gas is required. This is commonly done

by a chain arrangement which runs from the gas-holder to the injector and comes into action when the gas-holder is at its top position. This stoppage of the blast tends to cool the fire, and as the gas-holder falls, the steam-jet will again come into action at full force, and a further cooling will take place, due to the impingement of a full blast of steam. These wide variations of blast lead to such variations in the temperature of the furnace that at times operations must be stopped, so as to blow up the fire, the gas-holder shut off, and the poor gas made thrown away. A large gas-holder which the engine can draw upon to keep going is therefore necessary, and also the constant attention of a man.

In the plant shown in Fig. 409 the injector, with its forty pounds of steam pressure placed at B, is always acting on the water-seal D, and owing to the fact that the return-pipe E leads back to the seal, the injector is either acting upon the gas-holder when the gas-holder is at its top position and the gas return-valve open, or is acting upon the generator when the valve is shut and the gas-holder down. The tendency of the injector is to act on the gas-holder, as there is less resistance to the pipe than from the generator. Steam and air at atmospheric pressure are led through the saturator I into the open ash-pit, and the mixture can only enter the generator when the injector is drawing upon it, and only in the quantity required. An even temperature of fire in the generator is obtained, and a uniform quality of gas is made automatically with varying loads. The gas return-valve is opened by the catch H when the gas-holder is in its top position, and the gas is then constantly recirculated from the gas-holder to hydraulic box and through the cleaning apparatus. The steam at B aids greatly in cleaning the gas. With this plant the gas-holder, now a regulator, is continually moving slightly up and down near its top position.

In Fig. 410 we illustrate a wood-fuel gas-producer, the design of M. Roché, Paris, France, which brings out the possibilities of utilization of saw-mill waste, slabs, and sawdust, and the waste of wood-working mills for the production of power-gas.

It consists of a central furnace in which the fuel charge is burned and which is surrounded by a series of retorts. The fuel used is wood or wood-waste matter, and the products of combustion in the furnace F pass through the flue E and around the retort B. Fuel

is fed to the upper part of this retort, which is sealed, and the gas is distilled off by the high temperature maintained. The only exit of the retort is at the bottom, and in travelling down through the retort the gases pass through the lower bed of fuel, which is at a very high temperature, being practically in a state of incandescence. Any condensable gases or vapors in this part of the retort are broken up and fixed so that the gases which pass through the U-shaped pipe L to the holder K are in the condition of permanent gases. When wood is used as fuel the composition of these gases is about 18 per cént. carbonic acid, 22 per cent. carbon monoxide, 15 per cent. methane, and 45 per cent. hydrogen. The calorific value of the gas is about 346 British thermal units per cubic foot. While this is quite high it should be remembered that it is generated by distillation, and is therefore free from nitrogen, which usually forms about 50 per cent. of the volume of producer-gas made by combustion, and it also contains a larger proportion of hydrogen. The products of combustion in the furnace F, after circling around the retort, pass out the upper flue H, through the opening in the damper I, and out the exhaust-passage J.

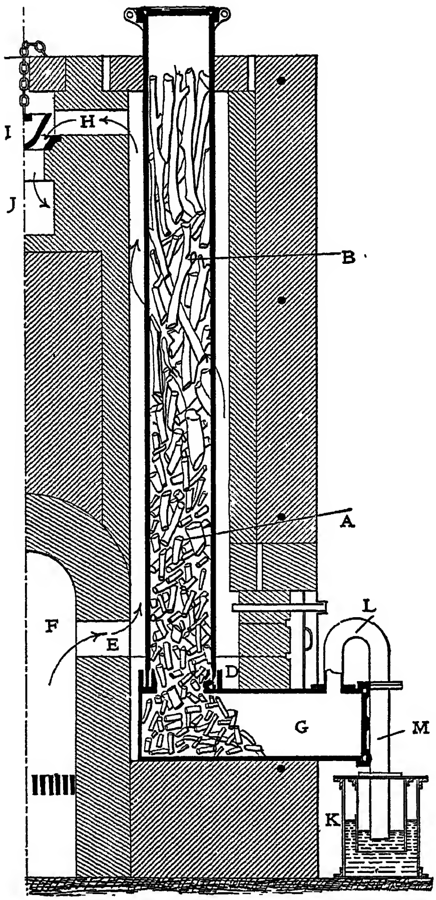


FIG. 410.—Riché distillation producer.

In Fig. 411 is illustrated the suction gas-plant of the Fairbanks-Morse Company, Chicago, Ill.

The plant consists of generator A, a scrubber B, a gas-tank or receiver C, and the economizer or vaporizer D. The generator is fitted with stationary cast-iron grates, and lined with fire-brick up to the gas-outlet. It is surmounted by a coal-hopper or charging reservoir of large capacity, which reduces the frequency of charges. Poke-holes are so located in the top of generator as to permit ramming down any clinker which may collect by the use of inferior grades of fuel.

Upon leaving the producer the gases pass through the vaporizer or economizer D, which is constructed with large gas-passages for the purpose of avoiding the objectionable clogging which results

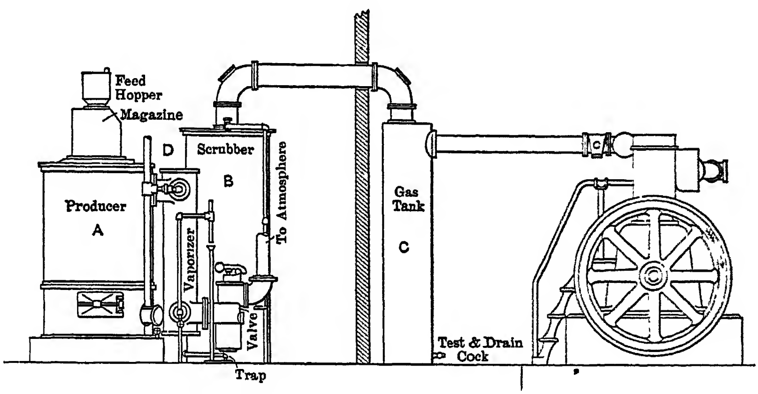


FIG. 411.—Suction producer-gas plant.

with the use of a multiplicity of small tubes of the vertical tubular-boiler construction.

Upon leaving the vaporizer the gas passes to a combined three-way and relief-valve, this valve being so constructed as to either vent to the atmosphere or through the scrubber, and also to serve as an automatic safety-valve which will vent gas to the atmosphere in case any excess pressure should accumulate in the system for any reason. Passing from the relief-valve the gas enters the lower part of the scrubber, which is built of unusual height, thereby cleaning the gas thoroughly before its passage to the purifier or engine.

The scrubber is provided with cast-iron grates and a water-pocket in its base, and filled full of coke. A spray-valve or nozzle is located in the centre of top of the scrubber and is of such design as to

permit carrying full water pressure at the valve itself and control the amount of spray by adjustment of the nozzle.

From the scrubber the gases are taken out at the top to prevent carrying an unnecessary amount of moisture to the engine. The gas passes next to a gas-tank or receiver C, which serves to condense any moisture or by-products present in the gas and carry them down its side to its base, which is provided with hand-hole openings and cleaning facilities. This enlargement of pipe, or receiver as it is called, also provides sufficient storage of gas immediately adjacent to the engine-cylinder to insure always a full cylinder-mixture and also produces a relatively steady draft through the producer and constant action of the fire.

Test-cocks are provided at the three-way valve mentioned and also in the base of the gas-receiver, which make it possible to determine the value of the gas before any attempt is made to put the engine in service.

A sawdust purifier is furnished and installed between the scrubber and engine, whenever the character of the fuel to be used in the producer is of such nature as to make additional cleaning necessary.

Considerable attention has been given to the detail of design with a view to facilitating inspection and cleaning of the various parts and insuring continuous and economical service. All principal piping connections are flange-fitted, having elbows provided with hand-holes to permit of cleaning in both directions. All principal water connections have T's or crosses for the same purpose, and cleaning doors and openings of liberal dimensions are provided in each one of the members.

These suction-plants are built in units of from 21 to 150 horse-power each and installed for powers as large as desired. For plants larger than 150 horse-power two or more units are furnished and so piped as to make engines and producers completely interchangeable.

Plants of various sizes have been installed which operate continuously 24 hours per day, six days per week, and endurance tests have been conducted which demonstrate that a producer-gas installation is in every respect as dependable as the best laid-out steam-plant.

In Fig. 412 we illustrate a German suction gas-producer plant

of the magazine-generator type, with some peculiarities worthy of note.

Reference to the diagram, which represents a section through the plant, will make the matter clear. A is the generator, which is a cylinder of wrought or cast iron with a fire-brick lining. A[1] is a small hand-fan which is attached to the producer, and which is used for starting purposes. B is the vaporizer, consisting of a grilled pipe passing through a water-jacket as shown. Its function is to vaporize the small quantity of water required in the generator. C

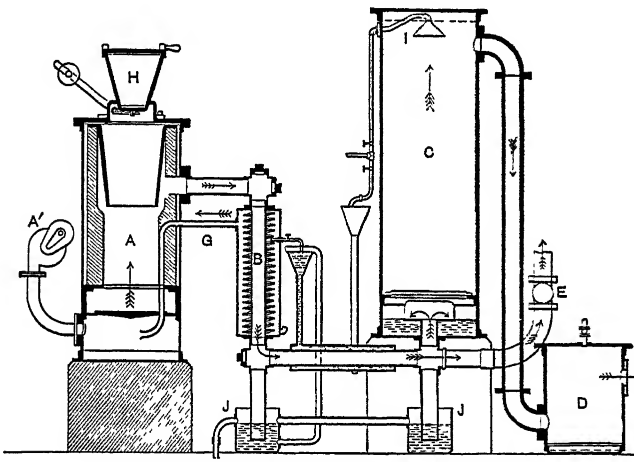


Fig. 412.—Sectional view of suction gas-plant.

is a coke-scrubber for cleaning the gas, and D is a gas-box fixed close to the engine. The fire is lighted in the fire-box by means of oil-waste and ordinary kindling. Anthracite coal or coke is put into the generator through the hopper—the fire-box door is closed, the valve E is opened, and the fan A[1] is started. While the fire is being blown up, the smoke and hot gases—which resemble those from a smith's forge—pass through the vaporizer B and escape to atmosphere through the valve E. The passage of these gases heats the vaporizer and forms water-vapor, which is drawn into the bottom of the generator. After about six minutes the gas is tested by a small pet-cock. As it improves in quality the valve E is gradually closed, and the gas is driven through the scrubber, where it meets a stream of water from the rose 1, and so to the engine. There is another

test-cock at this point, and as soon as the gas is considered rich enough the valve E is entirely closed, and the engine is started. The vessels J, J are water-seals for collecting the surplus water from the scrubber.

It is a good practice, where electricity is available, to couple the small blowing fan directly to the spindle of a small electric motor. This is very useful, the cost is small, and it saves labor and gives the engine-driver time to oil up and look round his plant and engine before starting up. It also enables the driver to brighten up his fire from time to time when he is standing by during the dinner-hour or at any other time. For this latter reason the by-pass pipe to atmosphere which is used when the engine is not at work should be made as high as is conveniently possible, so as to create a draught and keep the fire alight during the dinner-hour. At some tests made with one of these suction-plants, burnable gas was being produced seven minutes after the fire in the generator was lighted, and the engine was working on its load three minutes later. This may have been exceptional, and as a general rule 15 to 20 minutes from cold is ample for starting purposes. With these plants it is desirable to have a fairly large capacity in the generator-hopper, so that stoking need be less frequent and so that the coal can be warmed and dried before it actually comes into contact with the fire. It is also desirable to have a fairly large capacity in the generator, so that if the fire is dirty, or the coal contains shale, the production of gas does not suffer. The consumption of anthracite coal in a suction-plant is one pound per brake horse-power per hour, but a brake horse-power hour has been obtained on test from 0.6 of a pound of coal, and it seems probable that in future the consumption will be considerably below one pound.

Regulations of the National Board of Underwriters in Regard to the Installation and Operation of Producer-Gas Plants:

1. Pressure Systems.—All pressure systems must be located in a special building or buildings approved for the purpose and at such distance from other buildings as not to constitute an exposure thereto.

2. Suction Systems.—(*a*) A suction gas-producer of approved make, having a maximum capacity not exceeding 250 horse-power, may be located inside the building, provided the apparatus for producing and preparing the gas is installed in a separate, enclosed, well-ventilated, fire-proof room, with standard doors at all communicating openings.

The installation of gas-producers in cellars, basements, or any other places where artificial light will be necessary for their operation, is considered hazardous, and will not be permitted except by special permission of the underwriters having jurisdiction.

(*b*) The smoke and vent-pipe shall, where practicable, be carried above the roof of the building in which the apparatus is contained, and adjoining buildings, and when buildings are too high to make this practicable, the pipe shall end at least ten feet from any wall. Such smoke or vent-pipes shall not pass through floors, roofs, or partitions, nor shall they, under any circumstances, be connected into chimneys or flues.

(*c*) Platforms used in connection with generators must be of metal. Metal cans must be used for ashes.

(*d*) The producer and apparatus connected therewith shall be safely set on a solidly built foundation of brick, stone, or cement.

(*e*) While the plant is not in operation the connection between the generator and scrubber must be closed, and the connection between the producer and vent-pipe opened, so that the products of combustion can be carried into the open air. This must be accom-

plished by means of a mechanical arrangement which will prevent one operation without the other.

(*f*) The producer must have sufficient mechanical strength to successfully resist all strains to which it will be subjected in practice.

(*g*) Wire gauze, not larger than sixty mesh or its equivalent, must be used in the test-pipe outlet in the engine-room.

(*h*) If illuminating or other pressure gas is used as an alternative supply, the connections must be so arranged as to make the mixing of the two gases, or the use of both at the same time impossible.

(*i*) Before making repairs which involve opening the gas passages to the air, the producer-fire must be drawn and quenched, and all combustible gas blown out of the apparatus through the vent-pipe.

(*j*) The opening for admitting fuel shall be provided with some charging device so that no considerable quantity of air can be admitted while charging.

(*k*) The apparatus must have name-plate giving the name of the device, capacity, and name of maker.

CHAPTER XXV

PATENTS

ISSUED IN THE UNITED STATES FOR GAS, GASOLINE, AND OIL-ENGINES AND THEIR APPLIANCES, FROM 1875 TO OCT. 1, 1909, INCLUSIVE

1875

G. W. Daimler	168,623
J. Taggart	161,454
P. Vera	160,130

1876

J. Brady	176,588
A. de Bischop	178,121
T. W. Gilles	179,782

1877

J. Wortheim	192,206
R. D. Bradley	187,092
F. Deickman	195,585
N. A. Otto	194,047
Otto & Crossley	196,473

1878

J. Brady	200,970

1879

F. Burger	222,569 222,660
J. H. Connelly	211,836
J. Robson	220,174
Wittig & Hees	213,539
G. W. Daimler	222,467

1880

E. Buss	226,972
L. Durand	232,808
C. Linford	232,987
A. K. Rider	233,804
Wittig & Hees	225,778
D. Clerk	230,470
G. W. Daimler	232,243

1881

E. Renier	247,741
C. J. B. Gaume	240,994
A. K. Rider	245,218
J. Robson	243,795
G. Wacker	242,401
N A. Otto	241,707
J Ravel	236,258

1882

C G. Beechy	264,126
R. Hutchinson	253,709
A. P. Massey	260,587
T. McAdoo	253,406
P. Munsinger	266,304
L C. Parker	269,813
C. M. Sombart	260,620
K. Teichman	269 163
H. Wiedling	259,736 269,146
A. K. Rider	267,458
E. W. Kellogg	265,423
H. H Burritt	258,884
W. H. Wigmore	260,513

1883

C. W. Baldwin	276,747 276,748 276,749 276,750 276,751 287,897 288,399 290,310
J. Charter	270,202 270,203
H. Denney	290,632
Eteve & Lallemont	272,130
J. A. Ewins	278,421
E. J. Frost	273,269
W. Hammerschmidt	288,632
Geo. M. Hopkins	284,555 284,556 284,557

G. M. & I. N. Hopkins	284,851
Jackson & Kirkpatrick	283,398
S. Marcus	286,030
H. S. Maxim	273,750 279,657
L. N. Nash	271,902 278,255 278,256 289,019 289,691 289,692 289,693
N. A. Otto	288,479
L. C Parker (reissue)	10,290
G. H. Reynolds	284,061 284,328 287,578
J. Robson	278,600
C. Rohn	280,083
C. Shelburne	277,618
T. W. Turner	289,362
L. C. Parker	287,855

1884

G. M. Allen	301,320
J. Atkinson	306,712
J. Charter	292,894
E. Edwards	300,453
C. J. B. Gaume	302,478
Geo. M. Hopkins	306,254
G. M. & I. N. Hopkins	305,452
I. N. Hopkins	306,924
C. W. King & A. W. Cliff	293,179
S Lawson	306,933 307,057
H. S. Maxim	295,784 296,340
J. A. Menck—A. Hambrock	295,415
P. Murray, Jr	305,464 305,465 305,466 305,467
B. Parker	308,572
F. W. Rachholds	301,009
J. Spiel	302,045
W. L. Tobey	306,443
S. L. Wiegand	297,329
J. S. Wood	300,294
A. K. Rider	292,178
C. G. Beechey	306,314
S. Marcus	306,339
H. S. Maxim	296,341 291,065 293,762 302,271 293,185
J. Spiel	291,102
C. H. Andrews	301,078
J. Schweizer	292,864
N.H.Thompson & C.B.Swan	300,661

1885

S. Wilcox	332,312
C H. Andrews	314,284
C. W. Baldwin	325,377 325,378 325,379 325,380
C. Benz	316,868
M. G. Crane	327,866
G. Daimler	313,922 313,923
W. A. Graham	330,317
H. Hartig	324,554
G. M. & I. N. Hopkins	326,561 326,562
T. McDonough	315,808
L. N. Nash	312,494 312,496 312,497 312,498
J. F. Place	322,477 328,970
D. S. Regan	333,336
C. Shelburne	322,650 332,447
D. S. Troy	317,892
S. Wilcox	332,313 332,314 332,315
J. S. Wood	328,170
A. W. Schleicher	314,727
H. P. Feister	324,244
E. Schrabetz	312,906
L. N. Nash	312,499 331,078 331,079 331,080 331,210
D. S. Regan	320,285

S. Sintz	315,082
G. M. Ward	311,214

1886

C. H. Andrews—H. Williams	341,538
G. C. Anthony	337,226
J. Atkinson	336,505
J. Charter	335,564
J. H. Clark	347,469
G. Daimler (reissue)	10,750
E Delamare — Deboutteville	333,838
J. Hodgkinson—J. H. Dewhurst	347,603
E. J. J Lenoir	345,596
J. J. E. Lenoir	335,462
P Murray, Jr	351,393 351,394 351,395
L. H Nash	334,039 341,934 341,935
N. E Nash	340,435
J. F Place	348,998 348,999
N B. Randall	355,101
A L Riker	349,858
C. Sintz	339,225
H & C E Skinner	335,971
R F. Smith	345,998 347,656
J. Spiel	349,464
S. Wilcox	343,744 343,745
L H. Nash	334,038 334,040
E Korting	346,374
J H. Clark	353,402
C. E. Skinner	352,368 335,970
F. Bain	354,881
C. W. Baldwin	352,796
N. A Otto	350,077
H Robinson	346,687
N A. Otto	335,038
J. P. Holland	337,000 335,629
A. K. Rider	349,983
G. Daimler	334,109
J. Spiel	349,369
G. Ragot & G. Smyers	350,709
L. H. Nash	334,041

1887

J. Atkinson	367,496
C W. Baldwin	368,444 368,445
H. Campbell	367,184
J. Charter	356,447 370,242
L. T Cornell	359,920
F W Crossley	370,322
C. J B Gaume	374,056
F W Ofeldt	356,419
A Schmid—J C. Beckfield (reissue)	362,187 371,793 10,878
R Van Kalkreuth	358,134
J. S Wood	363,497
N C Bassett	359,552
T. Shaw	367,936
W Gavillet—L Martaresche	357,193
E Korting	366,116
F Von Martini	358,796
T. Backeljan	364,205
H P Holt—F. W. Crossley	370,258
N. A Otto	365,701
F. W Crossley—H P. Holt —F H Anderson	363,508
B. F. Kadel	374,968

1888

H T Dawson	392,191
E. Delamare—Deboutteville (reissue)	10,951
H Hartig	391,528
I N Hopkins	379,397
E. Korting	377,623
L. H. Nash	386,208 386,210 386,211
J. Noble	379,807
H. K. Shanck	376,212 390,710
W. S. Sharpneck	391,486
C. Sintz	383,775
H Skinner	389,608
R. F. Smith	377,962
G. W. Stewart	381,488
J. Bradley	386,233

J. R. Daly	392,109
L. H. Nash	386,214 386,216 386,212 386,213 386,215 386,209
R. Bocklen	384,673
N. A. Otto	388,372
H. Williams	386,949
N. A. Otto	386,929
A. Rollason	391,338 394,299
C L. Seabury	393,080

1889

A. Schmid—J. C. Beckfield	403,294
J. J. R Humes	400,850
C W. Baldwin	407,320 407,321
C. W. Baldwin	408,623
T. B. Barker	400,163
J C. Beckfield	396,022
L T. Cornell	406,263
W. E Crist	417,471
H. J. Hartig	415,197
A. Histon	400,458
S. Lawson	399,907 399,908 402,749 402,750 402,751
J. Mathies	411,668
L. H. Nash	401,453 418,417
D. S. Regan	408,356
N. Rogers—J. A. Wharry	403,379
A. Schmid	396,238
C. Sintz	416,649
H. Tenting	402,363
W. von Oechelhaeuser	417,759
C. White—A. R. Middleton	406,807
L. F. McNett	407,961
N. Rogers—J. A. Wharry	403,378
W. E. Crist	417,472
L. H. Nash	418,419
E. D. Deboutteville—L. P. C. Malandin	400,754 411,644
E. Capitaine	408,460
E. Korting	417,924
N. Rogers—J. A. Wharry	403,377 403,376
L. H. Nash	401,452
L. C. & B. Parker	401,204
E. Capitaine	408,459
I. F. Allman	411,211
N. Rogers—J. A. Wharry	403,380
J. C. Beckfield	417,624
S. Griffin	412,883
H. Hoelljies	408,483
L. H. Nash	418,418
E. Capitaine	406,160
C. S. A. H. Wiedling	398,108
J. J Purnell	408,137
S. Wilcox	402,549
L C. & B. Parker	403,367 405,795
W. J Crossley	406,706
G. Daimler	418,112
J. Charter	415,446
N A. Otto	407,234
M. V. Schiltz	399,569
A. Allmann–F. Kuppermann	412,228
K. Gramm	415,908

1890

G. B Brayton	432,260
W D. & S. Priestman	430,038
E. Butler	423,214 437,973
H. Lindley & T Browett	440,485
N. A. Otto	433,806 433,807
H. Campbell	428,801
G. McGee	432,638
J. Taylor	443,082
N. A. Otto	433,809 433,810 433,811 433,812 433,813 433,814 437,508 424,345
M. M. Barrett—J. F. Daly	434,695 430,504
F. Dürr	442,248
H. J. Baker	421,473
C. W. Baldwin	434,171

M. M. Barrett—J. F. Daly	430,505 430,506
J. C. Beckfield	432,720
J. C. Beckfield—A. Schmid	421,474 421,475 421,477
E. H. Gaze	437,776
J. Mohs	426,297
E Quack	441,582
D S. Regan (reissue)	11,068
A. Schmid—J C. Beckfield	421,524
H. K. Shank	439,200
W S. Sharpneck	441,028
C. Sintz	426,337
J. D Smith	418,821
E A Sperry	433,551
J. R. Valentine—A T. Grigg	425,116
C W. Weiss	419,805 419,806
C. White—A R Middleton	438,209
J J. Pearson—J Kunze	428,858
G H. Chappell (Rotary)	441,865
J H Eichler (Rotary)	442,963
G E. Hibbard (Rotary)	424,000
W S. Sharpneck (Rotary)	428,762
W. C. Rossney	420,169
E F. Roberts	424,027
C W Baldwin	439,232
J J. Pearson	426,736
J. W. Eisenhuth	436,936
J. W. Eisenhuth	430,310 430,312
G B. Brayton	432,114
A W. Schleicher—P A. N. Winand	434,609
P A. N. Winand—L V Goebbels	435,637
J. Roots	425,909
H A. Stuart	439,702
N. A. Otto	437,507
C. von Lude	435,439

1891

A. Harding	452,520
I. F. Allman	453,071
J. Charter	455,388
B. H. Coffee	446,851
P. T. Coffield—C. H. Poxson	456,284
E. W. Evans	452,568
J. Fielding	450,406
M. A. Graham	445,110
O. Kosztovits	448,924
G. W. Lewis	451,621
E. Narjot	448,989
B. C. Vanduzen	448,597
G. J Weber	449,507 444,031
M. M. Barrett	452,174
M. M. Barrett—J. F Daly	463,435
D. D. & J. T. Hobbs	460,070
F. W Lanchester	459,403 459,404 459,405 465,480
L G Wolley	450,091
J S. Connelly	457,459 457,460
V. Loutsky	460,241
P Neil—A Janiot	462,447
H. Williams	457,020
B. C. Vanduzen	448,386
P. C Sainsevain	461,802
G. Roberts	446,016
F. S. Durand	455,483
H. Schumm	458,073
H Lindley	450,771
E. Kaselowsky	463,231
G. W. Lewis	451,620
A. Rollason—J H Hamilton	456,505 456,853 457,332
O. Lindner	453,446
L Kessler	451,824
D. S. Regan	448,360

1892

J Joyce	480,019
B. Stein	478,651
D. Best	484,727
J Charter	472,106
J A. Charter	473,293 477,295
H. T. Dawson	466,331
E. W. Evans	488,165
J W Raymond	488,483
H. Warden	486,143
J. Wehrschmidt	484,168
C. W. Weiss	473,685
S. Withers—D. S. Covert	487,313
H. Schumm	488,093

E. I Nichols	480,272
H. Schumm	482,202
A. Niemezyk	480,737
G. W. Weatherhogg	480,535

1893

F. E. Tremper	495,281 503,016
J. S Bigger	491,403
F. Cordenons	500,754
J. Foos—C. F. Endter	494,134
C J. B Gaume	501,881
W. W Grant	497,239
C F. Hirsch—A. Schilling	507,436
D. D. Hobbs	506,817
G E Hoyt	502,255 510,140
S. Lawson	498,476
G W. Lewis	511,535
W. von Oechelhaeuser—H. Junkers	508,833
C. W. Pinkney	499,935 504,614 505,327 511,158
J. W Raymond	491,855
C. Sintz	509,255
C. V. Walls	498,700
H. A. Weeks—G. W. Lewis	511,478
W. H. Worth	504,260
H. W Tuttle	510,213
D. Best	496,718
C W Weiss	492,126
A. Niemczyk	508,042
C B. Wattles	509,981
E Delamare—Deboutteville—L. Melandin	511,593
H. Schumm	497,689 510,712
C. Stein	511,661
P. H. Irgens	505,767
H. Williams	490,006
B. Chatterton	505,751
A. Gray	504,723
W. Seck	509,830

1894

J. Low—J. W. Gow	515,297
P. A. N. Winand	525,828
A. J. Painter	523,369
W. S. Elliott, Jr	523,628
H. F. Frazer	526,348
J. B. Carse	518,177 518,178
B H. Coffey	514,211
H. T. Dawson	513,486 530,508
W W. Grant	525,651
J W. Hartley—J. Kerr	515,770
C. F. Hirsch	526,837
F. Hirsch	522,712 530,523
C. S Hisey	514,713
J. Labataille—J. J Graff	517,821
D C. Luce	519,863
J McGeorge	525,857
F. S. Mead	528,006
H B Migliavacca	528,105
E Narjot	515,530
F C. Olin	525,358
J. & W. Paterson	528,489
T. H & J T. H. Paul	530,237
H Pokony	514,271
S D. Shepperd	521,443
H Swain	519,880
R Thayer	517,077
H Voll	527,635
J. Walrath	522,811
F Hirsch	518,717
W W. Grant	514,359
K. A. Jacobson	514,996
M. Lorois	529,452
W. A. Shaw	523,734
W F. West	513,289
W. Seck	517,890
H. M. L Crouan	515,116
H. H. Andrew—A. R. Bellamy	526,369 528,063
H. Schumm	528,115
H. Campbell	523,511
L. Crebessac	530,161
R B Hain	531,182

1895

G. W Waltenbough	543,116
H. Schumm	548,142
F. M. Underwood	542,743
F. S. Mead	546,238
H. Thau	545,553
A. J. Signor	538,132

C L. Ives	534,886
M L. Mery	543,157
C. W Weiss	543,163 543,165
J J. Norman	548,922
J J Bordman	547,414
J Bryan	542,972
E. E Butler	546,110
J A Charter	532,314
F. W. C Cock	544,210
F W Coen	551,579
G F Conner	548,628
F E Covey—G. W. Haines	532,869
W. L Crouch—E. E. Pierce	535,815
J Day	543,614 544,214
H J Dykes	539,122
J Froelich	550,266
E R Gill	536,029
H H Hennegin	545,502
F. Hirsch	532,555
A R Holmes	540,490
L M Johnston	538,680
J. W Lambert	534,163 550,832
H. A Lauson—J. J. Norman—A D Nott	550,451
F. S Mead	541,773 545,709
F. P Miller	532,980
C M Rhodes	531,861 540,923
F. A. Rider—S. Vivian	533,922
B L Rinehart—B.M.Turner	552,332
C Sintz	539,710
E J. Stoddard	533,754
H Swain	535,964
G Van Zandt	537,253
C V. Walls	537,370
G J Weber	534,354
H A Weeks	543,818
C. J. Weinman—E. E Euchenhofer	537,512
C. White—A. R. Middleton	545,995
D Best	544,879
F. Burger	549,626
J. R. Bridges	548,772
J. W. Lambert	536,287
G W. Roth	552,263
W. R. Campbell	550,742
B W. Grist	545,125
J. Robison	532,098
P. Burt—G. McGhee	550,674
G W. Roth	539,923
F S Mead	544,586
J E Weyman—A. J. & J A Drake	542,124
P. Bilbault	532,412
A R Bellamy	536,997 537,963
O. Colborne	550,675
J Robison	532,099
C. & A Spiel	532,219
J E Friend	550,785
S Griffin	542,410
W Seck	549,939
H. F Wallmann	548,824
W E Gibbon	547,606
V. List—J. Kossakoff	535,914 536,090 550,185
A W Brown	532,865
F. Mayer	549,677
F. W. Ofeldt	538,694 540,757
W Lorenz	535,837
J Robison	532,097 532,100

1896

J F Duryea	557,469
J. F Daly & W. L Corson	557,493
G. E Hoyt	561,890
A A Hamerschlage	561,886
G. F Eggerdinger and G R Swaine	561,774
G. W. Lamos	562,307
Fred Mex	562,230
H G. Carnell	533,662 556,086
F. W. Mellars	556,195
C. J Weinman—E. E. Euchenhofer	555,717 555,791
F.W.Crossley & J.Atkinson	555,898
M G. Nixon	559,399
J. M. Worth	559,017
G. L. Thomas	558,749
C.Wagerell—A.A.Williams	555,355
W. W. Grant	553,460 553,488

S. M. Miller	553,352
F. M. Underwood	553,181
W. D. & S. Priestman	552,718
J. S. F. & E. Carter	552,686
L. J. Monahan—J. D. Termant	561,123
P. A. N. Winand	561,302
H. L. Parker	560,920
J. W. Eisenhuth	558,369
G. Alderson	560,016
A. F. Rober	560,149
L. H. Nash	563,051
T. M. Spaulding	562,673
L S. Gardner	562,720 558,943
E. Kasalowsky	559,290
I. F. Allman	556,237
H. C. Baker	563,249
F. S. Mead	563,670
A. W. Bodell	563,548
P. A. N. Winand	563,535
L. F. Allman	563,541
L. M. Burgeois, Jr	564,182
A. J. Pierce	564,643
E. N. Dickerson	564,684 565,157
H Swain	564,769
J. Robison	565,033
R. E. Olds—M. F. Bates	565,786
B. Wolf	566,263
A. Barker	566,125
H. Ebbs	566,300
G. H. Willets	567,530
H. A. Winter	567,432
H. Van Hoevenburgh	567,928
C. D. Anderson	567,954
J. S. Klein	568,115
J. S.—R D.—W. D. & C. H. Cundall	568,017
G. A Thode	568,814
F. C. Olin	569,386 569,564
H. A. Winter	569,530
C. J. Weinman—E E. Euchenhofer	569,365
H. Schumm	569,942
H. C. Hart	569,918
M. W. Weir	569,694
T. von Querfurth	569,672
R. E. Olds	570,263
E. J. Pennington	570,440 570,441
R Rolfson	570,649
L. Gathman	570,470
E Prouty	570,500
C. W Pinkney	571,239
C. A. Kunzel, Jr	571,447
G. W. Lewis	571,534
F. C. Olin	571,495
E Rappe	571,498
M. Blakey	571,966
J. F. Duryea	572,051
E. E Ludi	572,209
E. Capitaine	572,498
F. J. Rettig	573,296
F. E Culver	573,209
S M Balzer	573,174
J Charter, Jr	573,762
G S. Tiffany	573,628
M. F. Underwood	574,183
J. W. Eisenhuth	574,311

1897

F. Burger	576,430
F. C Southwell	575,812
J. Walrath	577,898 578,377
L. Benier	579,378
H. S Bristol	575,326
T W. Cohen	575,878
P. T. Coffield	579,789
O. Colborne	579,860
W. L Crouch	574,670 575,502
C. L Grohmann	574,535
G Joranson	574,610
J. Ledent	575,720
L. H. Nash	576,604 578,112
L. H. Wattles	577,567
G. W. Lamas	574,614
J. D. Blagden (Rotary)	575,517
E. W. Blum	579,554
W. Donaldson	577,160
E. Fessard	574,723
W. F. Trotter	575,661
W. Rowbotham	574,762 578,266
A. Peugeot	577,536
G. W. Lewis	577,189

O Bamborn	578,034
E. Merry	579,068
W. Maybach	577,167
M. Blakey	580,172
J G Lewis	580,090
G H. Ellis and J. F Steward	580,387
H C Baker	580,444
D. Best	580,446
F. G. and F H. Bates	580,445
W. O. Worth	581,683
E. P Woillard	581,385
A Winton	582,108
T. Small	581,783 581,784
F. S Mead	582,073
G Alderson	581,930
W H. Knight	581,826
O. Mueller	582,540
J W. Lambert	582,532
H. T. Dawson	582,271
F. M. Rites	582,231 582,232
J A. Charter	582,620
G. W Lewis	583,399
G. Westinghouse and E Rund	583,586 583,584 583,585
G. Langen	583,600
H. B Maxwell	583,495
L. H Nash	583,627 583,628
J. W. Raymond	583,507 583,508
J. H. Tuffs	583,872
F. Burger and H M Williams	584,282
F. C. Griswold	584,130
P. B. and S D. McLelland	584,188
W F. Davis	583,982
P. A. N Winand	583,962
J. O Brown	584,622
E B. Dake	584,674
C. C Wright and W. J. Stephens	584,448
C. Quast	584,961 584,960
C. A Miller	585,115
G. W. Starr and J. H. Cogswell	585,127
W. E. Gibbon	585,434
L. S Brown	585,504
H. B. Steel	585,601
F. Burger	585,651
J. A Charter	585,652
C. Jacobson	586,312
J. D Russ	586,321
E. P. Woillard	586,409
E J. Pennington	586,511
T. A. Redmon	586,826
A A. Williams	587,627
P. Mueller	587,747
H C. Hart	588,061 588,062
A G Pace	588,466
S. A. Reeve	588,292
C. Quast	588,876
L. Bly	588,629
White & Middleton	588,917
J. C Wilson	589,150
E. R. Moffitt	589,509
J. S. Walch	590,080
A. J. Tackle	590,796
V. G Apple	591,123
F. Conley and C J. Macomber	591,341
M. O Godding	591,598
D. Best (reissue)	11,633
C. I. Cummings and J C Hilton	591,952
C W Weiss	592,033 592,034
P Auriol	592,073
C L Mayhew	591,862
C Sintz	592,669
F. C Olin	592,881
F. W. Spacke	593,034
F. W Lancaster	562,794
J. J. Heilmann	593,296
C. A Schwarm	593,970
F. F. Snow	593,911
A. Rosenberg	593,859
W. Bayley	594,372
J. Q. Chase	595,043
McFadden and Lloyd	595,324
A. L. Harbison	595,625
E. Meredith	595,489
W. Rowbotham	595,497
J. B. Fenner	596,239
E. R. Bales	596,352
F. W. Lancaster	596,271

1898

W. J. Wright	607,904
W. E White	599,376
J. Madlehner and F. Hamilton	616,059
W. von Oechelhaeuser	596,613
W. O. Worth	607,613
J S. Klein	613,284 615,393
T. M. Doyle	602,556
F. S. Mead	603,914 612,258
H. A. Humphrey	611,125
W. Morava	608,968
W. R. Bullis	597,389
R. Diesel	608,845
F. L. Merritt	605,583
M. H Rumpf	615,049
G. L. Woodworth	607,317
G. H. Gere	598,986
R. B. Hain	599,653
W. F. Trotter	603,297
C. A. Lefebvre	614,114
A. A. Vansickle	615,766
P. E. Singer	600,971
A. Howard	602,161
G. A. Marconnett	611,813
E. Wieseman and J. Holroyd	600,107 600,974
S. Rolfe	597,860
S Bouton	606,504
L. Halvorson	600,147
C. E. Henriod	603,986
P. L. Hider	599,235
G. A. Newman	602,707
J. A. Secor	602,477
E. D. Strong	597,921
A. Winton	598,832 600,819 610,465
M. F. Bates	607,536
M. Beck	602,820
L. F. Burger	598,496
H. G. Carnell	613,757
J. Carnes and C. W. McKibben	603,125
F. E. Culver	601,012
A. H. Dingman	610,034
J. F. Duryea	605,815
J. Fraser	599,496
C. Guyer	596,809
H. H. Hennegin	597,771
T. H. Hicks	606,386
D. D Hobbs	613,417
C. Jacobson	607,566
J. N. Kelly and W. M. Kelch	610,682
J. Lizotte	600,675
S. E. Maxwell	601,210
L. H Millen	612,047
J. J. Ohrt	608,298
F C. Olin	613,390
J. A. Ostenberg	612,756
C Quast	597,326 607,878 607,879
J Reid	607,276
S. S Simrak	598,025
H. C. Strang	615,052
D. M Tuttle	604,241
B C. Vanduzen	600,754
W. E White	599,375
L J. Wing	607,580
W. J Wright	607,903

1899

A. G Pace (reissue)	11,775
R. Mewes	633,878
F. R. Simms	617,660
F R Simms (reissue)	11,763
E. Fessard	639,160
F. Burger	623,980
E Brillié	618,638
W. Jasper	626,206
E. J. Fithian	626,155
G Hirt and G. Horn	630,083
H. Smith	632,763
H. C L Holden	622,047
S. N. Pond	633,484
A. Howard	617,529
F. Hayot	623,713
C J F. Mollet-Fontaine and L. A. C Letombe	634,063
F. Durr	625,387
F. C. Hirsch	622,469
H. N Bickerton and H. W. Bradley	640,083
J. W. and P. L. Tygard	619,004
E. J. Stoddard	623,224
A. Mahon	625,180
S. W. Zent	637,317
C. A. Anderson and E. A. Ericksson	630,838

J. H. Frew	623,361
G. W. Lewis	621,110
H. J. Perkins	630,738
P. W. Weeks	635,624
J. H. Hamilton	621,525
J. B. Doolittle	637,450
C. O. White	634,679
J. A. Harp	628,316
E. H. Korsmeyer	636,048
E. L. Lowe	624,355
J. W Eisenhuth	620,554
E. J. Woolf	627,219 627,220
C. R. Daellenbach	632,917 632,918
L. B. Doman	625,839
T. C. Kennedy	621,572
G. W. Lewis	620,941
H. P Maxim	620,602
J. A. Secor	623,568
F. H Smith	636,298
H. Smith	624,555
E. J. Stoddard	623,190
E. E Truscott	617,372
J. Walrath	632,859
A. Winton	617,978 626,120 636,606
S. A. Hasbrouck	624,649
J. W Eisenhuth	620,431
E. E. Allyne and R. G Anderson	622,876
C R. Alsop	618,972
S. A Ayres	632,888
E and W. F. Bauroth	617,388
C. P Blake	631,003
C W Bogart	628,518
J. O. Brown	635,294
F. Burger	632,913
W. H. and J. Butterworth	624,750
O. F. Good	634,686
E. W. Graef	622,891
J. D. Hay and B. M. Bullock	632,814
L. J. Hirt	620,926 629,904
L. S. Kirker	627,338
H. A. Knox	627,857
A. Lee	634,529
P. Murray	619,776
A. H. Neale	639,683
R., Sr., and R. Nuttall, Jr.	631,224 640,018
G. Palm	618,435
C Quast	624,975
E Rappe	637,975
J. W. Raymond	636,451
C. C. Riotte	616,974
W. S. Sharpneck	628,122 628,123 628,124 628,125
H. Smith	632,762
G S Strong	637,298
T J. Sturtevant	634,509
A. A. Vansickle	620,080
G A. Whitcomb	634,654
J. Williams, Jr	636,478
E E Wolf	618,157
C Hoerl	633,380
G Dahlberg, J Clicquennoi and E Uhlin	633,338 633,339
J. H. Hamilton	621,526

1900

J. W Eisenhuth	640,890 642,434
J L Baillie and P. B Verity	642,949
J F. Craig	644,004
J F. Duryea	646,399
G W. Lewis	640,674 640,675
T. Malcolmson	642,143
J A. Secor	640,711
C. Sintz	646,322
G A Tuerk	641,659
A Heil	645,293
W A. Kope	642,043
G. W Lewis	640,393 640,394 640,672 640,673
A. L. Navone	642,706
A. T. Otto	645,044
G. S. Shaw	641,156
J. Straszer	640,237
P. Robertson and C. Matson	641,727
B. M. Aslakson	644,566
A. J. Frith	644,798
E. Thomson	642,176

J. E. Thornton and J. P. Lea	644,951
A. G. New	642,871
L. Charon and F. Manaut	645,458
J. G. Lepper and W. F. Dial	644,295
A. Bink	644,843
E. Fahl	644,853
H. A. Frantz	644,590
C. O. Heggem	644,598
C. W Hunt	641,514
A. J. Martin	641,313
E. A. Sperry	643,258
H. Stommel	645,497
G. E. Whitney	642,771
G. E. Whitney and H Howard	642,943
W. O. Worth	645,378
A. Olson	643,525
J. W. Lambert	640,667 640,668
L. Jones, Jr	645,398
F. J. Macey	643,513
C. R. Alsop	640,252
G W. Lewis	640,392 640,395
H. F. Probert	642,366 642,562
D Drawbaugh	643,087
W J. Perkins and C. H. Blomstrom	643,002
F. R. Simms	642,167
W. Banes	644,027
E T. Headech	646,282
J. C. Anderson	651,741
J. Craig, Jr	650,525
G A. Fleury	651,966
C. A. Scott	647,583
T. Cascaden, Jr., and T. C. Menges	652,470
A. H. Goldingham	650,583
H. Sutton	650,736
W. J. Woodward and D. Barckdall	649,713
J. H. Atterbury	652,382
W. R Dow	647,651
W. W. Gerber	652,539
J. S. Losch	650,789
C. A. Miller	652,544
C. K. Pickles and N. W. Perkins, Jr	652,724
F. W. Toedt	650,549 651,216
A. Martini	651,875
E. Funke	650,312
J. McLean	646,452
H. Swain	650,571
H. Crouan	651,237
J. Wickstrom	650,576
A. Adamson	651,062
H. T. and H. A. Dawson	651,780
V. R. Stewart	650,661
H. A. Bertheau	648,914
C. E. Belcher	650,816
T. Croil	652,534
T B Dooley	651,323
J. Greffe	652,673
R. Hagen	646,982
F. K Irving	646,993
F. A. La Roche	652,278
A. H. Overman and J. H. Bullard	648,286
R. M. Owen	652,486
L. W. Ravenèz	650,950
E. S Sutch	648,059
O. Waechtershaeuser	652,571
J. A. Ostenberg	648,520
W. J. McDuff	650,266
O. Owens	646,867
L. Hutchinson	648,689
E. S Haines	652,104
W. F. Davis	648,122
W. H. Cotton	647,946
D. M. Tuttle	649,778
J. C. Anderson	651,742
C E Duryea	649,441
W. E Cary	657,810
C. Hautier	656,020
F. C Olin	653,876
T B Royse	653,040
C. W Shartle and C. E. Miller	658,594
H. Smith	657,576
E. C Wood	655,473
G. W. Starr and J. H. Cogswell	657,140
S. F. Beetz	657,384
C. R. Daellenbach	653,379
O. J. Fairchild	656,101
H. A. Bertheau	655,186
F. J. Sproehnle	653,971

S. Messerer	654,996
V. V. Torbensen	653,854
R. H Little	656,823
E. Haynes and E. Apperson.	658,367
M. F Marmonier	657,226
R A Frisbie	656,539
G E Hoyt	657,934
W J. Baulieu	653,651
C L. Mayhew	652,909
J. J Simmonds	658,127
J. Rambaud	654,356
G. Palm	654,761
W E Simpson	658,595
S. W Rea	657,451
F. A. Law	653,353
L. Witry	655,289
G W Henricks	653,957
R. R. von Paller	655,269
C. H Blomstrom	657,055
A C von Fahnenfeld and E. S von Wolfersgrun.	653,341
J. G MacPherson	655,407
G. Kiltz	657,739
R. Diesel	654,140
F. A. La Roche	657,662
I. H. Davis	657,760
J. G MacPherson	655,406
H Wegelin	654,693
G. L Reenstierna	655,661
A. J. New	656,143
S. A Hasbrouck	654,894
H. C. Thamsen	654,818
L. S. Clarke, W. Morgan, and J. G Heaslet.	653,501
C. J. Coleman	653,167 653,168 653,169 653,170 653,172 657,516 657,899 658,238
P. J. Collins	655,853 656,389
E. P. Cowles	654,716
J. T. Dougine	655,329
C. E. Duryea	653,224
J. W. Eisenhuth	656,396
C. D. P. Gibson	656,962
H J. Lawson	654,797 658,068
H W Libbey	654,741
C. A Lieb	653,102
J. H Munson	653,199
L. J. Phelps	653,879
W. Scott	656,483
C. T. Shoup	658,046
F. E and F. O. Stanley	657,711
V. V. Torbensen	653,855
G. E Whitney	652,940 652,941 652,942 652,943 652,944
W. S Halsey	659,027
L. H Nash	658,858
J. M. Olsen	659,095
E. A Mitchell	658,993
A. A Williams	659,426
W F. Davis	660,073
D. E Barnard	659,911
H D Weed	659,944
P. H Standish	660,129
F. G. Bates	660,482
G. H Rogers	660,338
C Bonjour	660,412
F. Dürr	660,292
A. Hayes	660,954
J W Lambert	660,778
E. T Birdsall	660,786
J W. Lambert	661,181
G L Reenstierna	661,276
A. Johnson	661,291
A. and E. Boulier	661,439
T M and F. L. Antisell	661,300
F. C Dyckhoff	661,369
J B. Rodger	661,078
L. Charon and E Manaut	661,235
X. de la Croix	661,854
J Day	661,559
N. A Guillaume	661,865
M. Flood	662,189
F. R. Simms	662,317
A. J. Signor	662,315
T. L. and T. J. Sturtevant	662,040
A. J. Signor	662,155
G. J. Altham and J. Beattie, Jr.	662,181
G. A. Timblin (designs)	33,592

H. B. Steele	662,631
P. Swenson	662,507
O. F. Good	662,718
M S. Napier	663,388
H. W. Strauss	663,106
A. D Garretson	663,091
G. A Tuerk	663,798
W. H. Cotton	663,653
G. Buck	663,725
L. S. Clarke and J. G. Heaslet	663,729
F. R. Simms and R. Bosch	663,643
H. Smith	663,475
C. O White	664,110
A. T. Otto	664,360
L. H. Nash	664,025
C. O. White	664,200
J. Dougill	664,134
J. W. Eisenhuth	664,018
H. Sutton	664,689
G Miari and F. Giusti	664,661
W. K. Freeman	664,632

1901

W Maybach	668,111
C. E. Dawson	668,954
S Miller	667,846
H. L Arnold	666,838
S M. Zurawski	668,250
O. B. Johnson	669,416
E. Courvoisier	670,311
C. R. Daellenbach	665,881
L. H. Solomon	665,665
L. F. Burger	666,260
J. Walrath	669,272
E. Thompson	669,737
T. McMahon	670,803
W. O. Worth	670,550
W. E. Simpson	667,590
H. F. Walman	666,368
C. F. Bergman	665,849
H. L. Arnold	666,839
W. H. Aldrich	668,617
Kopp & Preston	674,421
J. A. McLean	674,979
G. A. Bronder	673,109
J. Eckhard	673,427
W. O. Worth	673,809
J. Rourk	674,709
M. L. Wood	676,523
G. L. V. Chauveau	671,160
C. C. and E. A. Riotte	671,934
Schumm & Munzel	675,796
J. Doorenbos	672,615
J. A. McLean	670,907
H. F. Wallman	677,048
H. Schwarz	676,449
J. Sterba	672,432
A. T Stimson	677,001
Tuck & Wassman	682,003
E. Butler	678,715
E. T. Birdsall	679,410
C. W. Weiss	680,953
C. E Duryea	682,606
W. J. Pugh	680,616
A. F. Bardwell	680,907
S. W. Zent	682,583
W. S. Sharpneck	680,985
E. N. Dickerson	681,111
C C Bramwell	678,823
R. R. Darling	679,367
M. W. Jamieson	681,704; 681,705
Campbell & Hawkins	682,788
B. F. Stewart	683,080
V. St. John	683,152
A. C. Wolfe	681,162
O. Snell	677,898
F. Reichenbach	682,567
Toepel & Widmayer	682,822
W. B. Cuthbertson	677,949
J D. McFarland	682,385
A. Tourand	687,084
E. J. Wolf	683,886
J. Valentynowicz	684,011
H. Enge	686,806
A. Hayes	688,245
F. Burger	684,743
W. S Halsey	684,813
M. E. Durman	687,678
H. M. McCall	687,924
C. L Mayhew	688,426
W. G Marr	688,536
M. F. Bates	689,351
J. Badeker	683,587
E. Caillavet	689,791
L. Genty	687,152
H. F. Wallman	688,907
C. A. Hirth	685,141
C. A. Marrder	685,722

Box & G. Labedan	686,801
J. H Reed	688,335
S. M. Williams	688,566
J. W. Plimpton	683,705

1902

F. D. Sweet	690,481
A D. Richardson	690,610
H. F. Wallmann	690,542
F. W. Toedt	691,083 691,084
E. Thompson	691,017
C Robinson	691,489
W. J. Pugh	692,071
W. A. Swan	692,218
T. Myers	693,529
G V. Petter	694,186
W. S & C Hibbard	694,016
A W. Clayden	694,090
H. Junkers	694,552
Freeman & Troop	694,735
C F Lembke	694,557
W. F. Davis	694,948
W. L. Judson	695,731
J D McFarland	696,251
E Thompson	696,518
P Burt	696,547
J A McLean	697,649
M. N Hylland	698,285
J V. Rice	699,014
R L Young	699,433
F Durr	699,503
J. W Stanton	700,100
W. J Robb	700,241
S S Rose	700,243
H A Bertheau	700,295
A. L Kull	700,785
J. T. Metcalfe	701,069
D. A Briggs	701,140
F. Reichenbach	701,505
F L. Nichols	702,375
C. W. Kelsey	701,891
J. S Rogers	702,246
J F. Hobart	702,430
F A. L. Sneckner	703,157
S. E. Poole	703,463
G. Wood	703,511
E B. and L. S. Cushman	703,695
G Gibbs	703,724
J. Lizotte	703,937
F Lister	704,060
C F. Cope	704,618
M J Klein	704,713
C. W Weiss	704,995
W Bernhardt	705,022
A. T Brown	705,201
M J Sullivan	705,881
R. L Barnhart	705,897
G. A. Graves	705,996
F R. Simms and R. Bosch	706,121
T Doherty	706,167
A. Vogt and M. von Recklinghausen	706,366
J. Lizotte	706,492
G. S. Andres	706,711
G Erikson	706,733
H. H and C. B Segner	706,859
G. Dahlberg, J. Clicquennoy, and E. Uhlin (reissue)	12,021
E. Estcourt	707,570
E. T. McKaig	707,793
C O. Hedstrom	707,922
R Diesel	708,029
J B Hicks	708,042
G. Dahlberg, J Clicquennoy, and E Uhlin (reissue)	12,024
A C Krebs	708,053
W A Leonard	708,236
C. W. Weiss	708,284
W J Still	708,502
A. T Bossett	708,518
W Heckert	708,637
A McCahon	709,030
H C Strang	709,060
B. C Van Duzen	709,126
F. B Warring	709,428
H A. Gray	709,598
C. W Weiss	710,026
P A. Prestwich	710,302
H. E. Barlow	710,312
R C. Marks	710,329
G. Westinghouse	710,385
P. F. Maccallum	710,483
L. W. Witry	710,647
W. G. Wilson	710,727
T. S Glover	710,771
C. W. Weiss	710,824
H. E. Ebbs	710,911
E G Shortt	711,235
W. J. Wright	711,454

J. F. Hill	711,628
E. S. Bowen	711,652
C. E Inglis	712,067
L. A. C. Letombe	712,393
C. O Hedstrom	712,791
W. L. Judson	712,805
W. M. Power	713,147
E. B. Parkhurst	713,194
J. McCoy	713,332
H. F Wallmann	713,366 713,367
J. A. Ostenberg	713,792 713,793
L. B. Smyser	714,049
C. Hendricks	714,180
C. A. Anderson, E. A Erickson, and J. Wickstrom	714,352 714,353
F Lagoutte	714,492
J. Hirst	714,799
F. G. Bates and B. A. Williams	714,853
J. W. Hinchley	714,902
C. C. Chamberlain	715,196
J. Lizotte	715,208
W. W. Tuck and A. Wassmann	716,314
B. F. Bain	716,615
F. E. and M. E Vaughn	716,792
C. E. Henriod	717,000
E E. Koken	717,417
E. J. Stoddard	717,466

1903

F. R. McMullin	717,902
J. F. Curtis and H F. Miller	718,131
W. P. Flint	718,334
W. Langdon-Davies and A. Soames	718,481
F. A Law	718,482
J. A. Ostenberg	718,511
H. F. Wallmann	718,552
P. Robertson and C Matson	718,658
H. J. Hurd	718,933
C. G. Armesley	719,072
C. E. Dawson	719,199
H. Gross	719,326
B. Niles	719,247
L. G. Woolley	719,407
H. W. Tuttle	719,536
J. Willoughby	719,547
W. M Everett	719,653
H. Morningstar	719,836
A. F Parks	719,855
L. A. Frayer	720,126
G. A. Ede	720,336
C L. Straub	720,752
H. W. Tuttle	720,759
C. A Bailey	720,995
L. P Mooers	721,065
E. H. Rousseau	721,238
J. Cereghino	721,285
A Evensen	721,872 721,873
C E Duryea	722,005
G W. Euker	722,176
B. Garllus	722,223
J. W. Packard	722,431
C. C. Riotte and C. R. Radcliffe	722,629
L. F. Burger	722,671
D. C. Stover	722,767
F. W. Toedt	722,774
G. Westinghouse and E. Rund	722,787
L. M. Johnston	722,846
T. C. Menges	723,540
H. Essex	723,660
A H Dingman	723,844
C W Weiss	723,956
J Dabled	724,239
F. W. Rogler	724,333
J B. O'Donnell	724,606
A M Zimmerman	724,648 724,649
W. Roche	724,945
J. A. Jenney	725,087
A. A. Low	725,104
R. A. Allsop	725,191
H. C. Strang	725,295
W. A. Whiling	725,528
G A Goodson	725,556
G. A. Goodson	725,644
E. W. Graef	725,700
C. A. Miller	725,741
L. F. Splitt	725,789
A. L. Riker	725,990
A. Krastin	726,226
G. A. Gemmer	726,671
L. A. C. Letombe	726,710

W J. McVicker	726,731
J McCluer	726,971
J S Lang	727,158
E. Maerky	727,399
M. H Rumpf	727,455
G. W. Starr and J. H. Cogswell	727,476
V. G. Apple	727,564
L. M. Foster	727,777
C. O Hedstrom	727,944
R. A. Mitchell and L L. Lewis	728,123
F. Reichenbach	728,297
R. D. Chandler	728,543
J H. Jones	728,724
H. M. McCall	728,747
J. S., R D, W. D, and H C. Cundall	728,873
W E. Dow	728,882
A. C. Mather	728,950
J. MacHaffie	729,194
J. C. White	729,467
J. MacHaffie	729,499
I. Lanster	729,613
C T Osborne	729,652
R. P. Thompson and E Koeb	729,700
H F. Wallmann	729,983 729,984
W. J. Boemper	729,995
A M. Coburn	730,345
S M. Balzer	730,433
F. G. Ericson	730,626
M H. Neff	730,683
M. Pivert	730,695
E E. Williams	731,001
C. E. Sargent	731,134
O. B Perkins	731,218
J. M Smelser	731,236
H. Austin	731,265
R. Cumming	731,286
K Schafferkotter	731,507
T. B. Jeffery	731,781
C. Rossler	731,956
A. T. Collier	731,995
A. F. Evans	732,343
H. G. Mears and H. W. Aylward	732,365
W. J. Wright	732,683
W E. Nageborn	733,256
H. F. Wallmann	733,350
H. A. Gilman	733,384
V. R. Nicholson	733,417
G. R. Albaugh	733,894
T. Charlton	733,902
A. L Riker	734,138
F. Bryan and A. H. Bayley	734,220
J. D. McFarland, Jr.	734,237
M. Offenbacher	734,356
P. Gaeth and A Griebel	734,415
A. Krebs	734,421
R. Cumming	734,827
G. A Goodson	734,851 734,852
J. M. Stadel	734,986
W. H Jones	735,035 735,036
F. C Hirsch	735,256
G C Eskholme	735,483
W Walke	735,627
W. C. Matthias	735,674
O. C Duryea and M. C. White	735,863
C. Schrotz	735,912
J. M Wilson	735,923
F. H Gile	735,964
J D McFarland, Jr	735,997
H. H Herm	736,132
E. B and L S. Cushman	736,224
P. Gervais	736,715
L. Jones	736,734
A A and D. E. Karcher	736,737
C. A Wilkinson	736,807
R. Diesel and H. Guldner	736,944
R. J. Voss	737,048
W. Brown	737,069
C. F. Pearson	737,463
B. L Toquet	737,532
C. F. Hitchcock	737,737
P. P. G. Hall, Jr	737,923
F. T. Cable	738,160
J. D Lyon	738,690
F. Charron and L. Girardot	738,772
W. W. Tuck, A. A. Low, and A. Wassmann	738,860
W. J. Wright	739,050
J. H Redfield	739,219 739,220
T. B. Jeffery	740,020
G. B. Fraley	740,117

C. R. James	740,138
H. Soeldner	740,195
R. P. Thompson and E. Koeb	740,488
G. Joranson	740,571
J. W. Sutton	740,711
T. L. and T. J. Sturtevant	740,781
C. F. Jaubert	740,864
E. C. Richard	740,924
J. A. Nickelson	741,064
R. Jensen	741,138
C. W. Spousel	741,178
F. Sproehnle	741,179
H. Guillon	741,329
J. W. Packard	741,365
J. W. Sutton	741,419
F. H. Smith	741,559
F. C Hirsch	741,791
C. M. Mohler	741,810
O. E. Pehrsson	741,824
J. A McGee	741,923
V. J. Emery	741,959
R. P. Thompson and E. Koeb	741,985
R. P. Thompson	741,986
H. Spuhl	742,079
W. J. Wright	742,143
R. R. Gaskell	742,184
L. Roedel	742,493
G. S. Billman	742,566
F. C. Hirsch	742,651
C. C. Chamberlain	742,774
O. P. Ostergren	742,799
E. E. Arnold and A. T. Kasley	742,820
E. N. Dickerson	743,064
G. A. Phail	743,097
G. C. Blasdell	743,230
W. Remington	743,327
M. H. Roberts	743,332
E. J. Stoddard	743,405
D. F. Graham and F. A. Fox	743,637
H. F. Wallmann	743,780
B. V. de Sutter	743,977
B. G. Holz	744,342
J. C. Meredith	744,380
R. C. Shepherd	744,418
L. S. Chadwick	744,486
W. W. Tuck, A. A. Low, and A. Wassmann	744,822
C. N. Cook	744,857
H. Sohnlein	744,881
R. Harris	745,055
G Erikson	745,098
J. Geisslinger	745,102
A. G. Melhuish	745,215
C. R. Daellenbach	745,422 745,423
C. G. Dean	745,578
H. Richter	745,669
R. B. Weaver	745,701
G Westinghouse	745,703 745,704
L. H Nash	746,133
W. C. Weatherholt	746,212
E. Korting	746,342
G J. Murdock	746,358
G. J. Rathbun	746,377
A. Krebs	746,527
W C. and S Hibbard	746,701
W. G Wilson	746,770
W. J Hurd	746,840
A McCahon	746,870
N. Crane	746,925
A. A. Low and A. Wassmann	747,620
B Wright	747,828
G McCadden	748,001
W Remington	748,011
H. G Underwood	748,029
W. M. Britton	748,045

1904

W. R. Kahlenberg	748,615
C. K. MacFadden	748,763
E. Prouty	748,883
H. H. and C B Segner	748,990
B. Banta and C. Mathews	749,654
T. S. James	749,864
E L. Russell	749,883
J. W. Swan	750,318
S Cunningham	750,349
W. W. Grant	750,451
B. Musgrave	750,478
B. H Pomeroy	750,489
H. Nelson	750,885
F. A. Seitz	750,901
A. A. Low	751,188
J. M. Johanson	751,292
R. Dempster	751,472

F. L. Chamberlin	765,814 765,880
H. M. Rawl and D. L. Reehl	766,116
A. Buchner and E. P McClure	766,166
F. Reynolds	766,525
P. Schmitz	767,369
A. A. Low	767,483
A. S. Dickison	767,549
N. E. Egge	767,556
L. Bayer	768,110
C. J. Everett	768,436
G. S Billman	768,506
W W. Tuck *et al.*	768,641
H C. Folger	768,793
E. Korting	768,807
H. Soeldner	768,866
L. D. Toliver	769,363
D. Clerk	769,589
M F. Bates	770,212
D. Roberts *et al.*	770,388
H. Sohnlein	770,872
W. Roche	770,927
J. W. Swan	771,028
M. Beck	771,037
E. C. Richard	771,095
O. P. Ostergren	771,320
W. C. Tompsett	771,511
G K. Benner and H. B. Nicodemus	771,601
S. E. Doane	771,616
P. P. G Hall, Jr.	771,631
D. R Morrison	771,881
C. W. Little	772,160
F Reaugh	772,178
W. B Hayden	772,235
C. H. Wisner	772,856
S. S. and A Lewis	773,021
R. and J. Cooper	773,062
F. E. Hall	773,206
F. M. Rites	773,339
R. Miller	774,392
C. W Hart	774,752
J. F. Duryea	775,103
F. Henriod-Schweizer	775,120
J. S. Losch	775,243
P. Schmit	775,314
P. J. Shouvlin	775,385
C. and W. Hibbard	775,819
J. S. Losch	775,908
J. W. Packard	775,932
M. H. Daley	776,118
E. P. Lamb	776,406
J. V. Ebel and W. J. Hudson	776,586
C. E. Sterne	776,700
F. J. Rochow	776,800
G. Marx, Jr.	777,295
W. I Spangler	778,082
J. Reek	778,146
A. M. Sweder	778,154
J. B. Morrison	778,261
H. F. Wallmann	778,289
K. Reinhardt	778,375
F. Lamplough	778,417
F. Reichenbach	778,707

1905

G. A. Brouder	779,116
H. Devlin	779,207
A. Bougault	779,256
H. M. Svebilius	779,328
E. T. McKaig	779,490
N. W. Traviss	779,509
F. J. Miller	779,727
F. W. Hagar	779,778
A. N. Parnall and E. W. Coryell	780,013
R. G. V. Mytton	780,119
J. G. Callan	780,549
A. E. Doman	780,555 780,559
S. F. and C. E. Burlingame	780,635
P. F. Maccallum	780,722
A. Radovanovic	780,812
E. R. Hewitt	781,064
T. Wright	781,484
P. C and E. R. Hewitt	781,604
J. W. Kales	781,607
E. J. Stoddard	781,751
A. Vogt	781,923
S. J. Webb	782,205

C. E Sterne and S J. Davis	782,471
W. B. Hayden	782,502
E. F. Hulbert	782,659
J. A. Arthur	782,812
C. R. Daellenbach	783,104
A. G. & C. R. Daellenbach	783,106
E. Martignoni	783,121
A E. Taylor	783,158
A. Hardt	783,194
C R Twitchell	783,336
H. Holzwarth	783,434
C E. Sargent	783,983
T. L. and T J. Sturtevant	784,191
G. McCadden	784,626
I. E. Hendman and J. J. Albright	784,677
C. J. Rousseau and E C Ferris	784,759 784,760
C A. Sawtelle	784,808
C W. Weiss	784,818
A Buchner and E. P. McClure	784,917
H J Leıghton	784,949
F A Haselwander	785,166
W. C. and M. W Risbridger	785,229
N. L. and W. W. Tuck	785,387 785,388 785,389
A M. Melson	785,428
A. Krebs	785,558
E. A. Rutenber	785,684
N L and W. W Tuck	785,687
M. E. Clark	785,713
L. D. Kinzig and G C. Riber	785,809
J. D. Termaat and L J Monahan	785,922
J. W. Packard	787,212
R. A. Mitchell and L. L Lewis	787,341
A. Willmer	787,487
C. W. Weiss	787,709
N. W. Hartman	787,918
R. H. Layton and J. E. Pfeffer	787,925
D. R. Morrison	788,057
C. S. Dutton	788,253
F. A. Haselwander	788,402
W. S. Browne	788,579
W J Perkins	788,594
H. J. Podlesak	788,595
J. P. Seaton	788,732
A F. Bauer	788,748
G A West	788,868
O Minton	788,929
W. C Weatherholt	788,972
L Mertens	789,047
L Brandenburg and C. N. Hiester	789,079
F. E. Youngs	789,246
H Gerdes	789,321
H. Richter	789,382
A Herz	789,426
H. Richter	789,673
E. R Langford	789,921
G A Aldrıch	790,018
H. B Steele	790,325
J. D Maxwell	790,374
C. B. Harris	790,833
T. L and T. J. Sturtevant	790,856
F. K De la Saulx	790,925
J Bartosik	791,071
D E. Barnard	791,126
W L Breath	791,447
E C Richard	791,501
C. A Dreisbach	791,757
A M. Brown	791,871
W. E Clıfton	792,119
R E. Olds	792,158
C. W Weiss	792,300
C D. Shain	792,670
D G. Williams	792,804
J. E. Green	792,894
F. L. Perry	793,091
W. J. Perkins	793,223
F X. Atzberger	793,263
H. E. B. Blomgren	793,270
V. R Browning	793,347
W B. Hayden	794,011
J W. Seal	794,192
W. J. Bell	794,275
C C. Riotte	794,683
J. F. Merkel	794,727
E. Westman	794,826
R. O. Le Baron	793,842
C. E. Sargent	795,236
A. Markman	795,295
F. A. Thurston	795,459
W. B. Hayden	795,698

J. L. Bogert	796,106
A. J. Postans	796,349
A. Houkowsky	796,425
A. Wassmann and A. A. Low	796,479
E. Soller and F. Hottinger	796,680
H. O. Westendarp	796,686
C. A. Carlson	797,555
F. C. Goddard	797,571
E. P. Gray	797,681
J. B. Moreland	797,972
M. Ferrero and A. Franchetti	798,328
W. H. Schoonmaker	798,366
A. Winton	798,553
T. B. Rennell	798,702
J. F. Duryea	798,995
A. P. Brush	799,029
W. B. Hayden	799,047
A. W. Jones	799,341
W. E. Collier	799,537
E. J. Grace	800,290
A. J. Haskell	800,372
A. Steinbart	800,770
C. S. Drummond	800,996
A. B. Calkins	801,645
R. H. Scott	802,665
L. D. Toliver	803,032
H. E. Thompson	803,078
E. T. Pollard	803,623
C. J. and V. E. Moody	804,332
A. Vogt	805,430
J. D. Blaisdell	805,774
F. J. Gowing	806,083
P. Schwehm	806,199
G. B. Selden, Jr	806,583
J. Williams, Jr	806,610
W. B. Hayden	806,664
N. W. H. Sharpe	806,715
D. L. Winters	806,860
A. G. Ronan	807,048
F. Berger	807,354
D. W. Lyon	807,835
R. Longtime and E. Double	807,950
E. S. Palmbla	808,210
A. Winton	808,423
1906	
N. Crane	808,902
R. Varley	808,958
T. Wright	809,082
J. F. Johnson	809,185
F. L. Orr	809,211
W. T. Fox	809,292
P. K. Stern	809,333
J. W. Kyle and J. W. Hicks	809,451
H. C. Holloway	809,614
J. W. Eisenhuth	809,791
G. Petzel	809,841
E. F. Porter and W. R. Whiting	810,347
W. G. Miller	810,495
H. Heinrich	810,535
E. F. Porter and W. R. Whiting	810,565
A. R. Bellamy	811,122
C. T. Hilderbrandt	811,220
F. Reichenbach	811,744
V. G. Apple	811,757
J. A. Williams	811,809
J. A. Williams	811,888
E. B. Robertson	811,955
E. G. Shortt	812,304
V. B Miller	812,584
H. J. Wiegand	813,068
C. M. Steele	813,250
R. Hartwig	814,287
G. Pendleton	813,736
H. K. Shanck	813,746
V. Erdmenger	813,959
E. C. Kavanaugh	814,609
F. M. Uhler	815,492
Ade Dion and G. Bouton	815,802
I S. Barnett	816,062
T. J. Lutz, Jr	816,109
L. F. Burger	816,215
W. Heckert	816,549
J. C. McLachlan	816,990
A. R. Curtis	817,104
G. N. McMillan	817,266
C. J. Rousseau and E. C. Ferris	817,671
J. S. Moreland	818,460
C. W. Weiss	819,258
T. B. Jeffery	819,283
J. B. King	819,557
J. W. Cross	820,285
F. H. Hurlbut and T. W. Munroe	820,497
D. M. Livingston	820,222

J. F. Crowley	820,626
H. G. Giffard	820,712
J. C. Scovel, Jr	820,891
S. B. Welcome	822,172
J. M. Morrison	821,370
H. B Nicodemus	821,373
P P G. Hall, Jr	821,410
L. Mertens	823,286
B. F. Stewart	823,450
G. H. Ellis	824,105
E J. Woolf	824,396
H. D. Dibble	824,528
M. C. Kessler	824,936
L. J. Monahan	825,923
W W. Henderson	826,101
L. A. Smith	826,123
A. B Goodspeed	827,302 827,304
H. J. Smith	827,759
P. Mohrdieck	827,810
J Boyle	827,904
J. W. Slater	828,064
G. Trinkler	828,352
H. Stoltenberg	828,867
B B. Mears	829,279
H. A. Frantz	830,144
R. Willetts	830,270
H. Dock	831,044
F. O. Farwell	831,048
F A Jahn	831,286
W. L. Morrow	832,268
C. E. Wisner	832,566
R. Hartwig	832,668
J Grouvelle and H. Arquembourg	832,901
A. Dina	834,566
T. N. Kellett	835,759
F W. Brady	835,773
J F. Jensen	835,908
H. O. Phillips	835,982
A Clement	836,093
C. J. Coleman	836,365
H. A. Johnston	836,503
S. N. Rapp	837,507
H. D. Murray and E. J. Fithian	837,708
C. Weidmann	837,989
J. W. Eisenhuth	838,013
E. J. Weeks	838,150
C. R. Greuter	838,399
H. G. Carnell (reissue)	12,572
J. Walsh and E. Swanson	838,926

1907

D. M. Tuttle	840,178
F. Wackenhuth	841,830
C. M. Gay	841,859
W. Dieter	842,182
J. Eckhard	842,392
J. T. Lagergren	842,468
C. A. Anderson, E. A Erickson and J. Wickstrom	842,607
C. White and A. R. Middleton	842,737
W. B. Burchall	842,844
W. von Oechelhaeuser	844,040
H S. Molony	844,825
H. A Stuart	845,140
W K Andrew	845,159
E. Evans	845,732
C. H. Brooks	846,004
H. G. Underwood	846,070 846,134
L. M. J. C. Levavasseur	846,487
S. A. Reeve	846,508
R. Varley and A. D. Scott	846,809
R. Varley	846,811
R. B. Benjamin	846,897
H. C. Royer	847,296
F. A. Haselwander	848,029
R. Varley	849,820
W. H. Ash	850,718
J. W. Lippincott	851,176
C. Schultz	851,779
H. J. Henry	853,303
D. Roberts	853,422
W. H. Hooper and F. S. Hutchins	854,002
R. Levering	854,096
H. E. Zastrow and J. H. Koepp	854,550
W. F. Brehm	854,981
P. Metzler	855,115
J. Stadtherr	855,209
J. H. and J. H. Birch	855,223
F. Morey	855,256
H. N. Bickerton, H. W. Bradley, and D. Clerk	855,442

A. R. Bellamy	855,611
C. E. Maud	856,647
E. H. Micklewood and H. Whidbourne	856,790
W. Morey, Jr	857,410
B. F. Stewart	857,120
A. B. Goodspeed	857,730
L. Iversen	858,071
F. von Handorff	858,280
W. A. Hansen	858,281
T. G. Wright	858,433
C. M. Gay	858,687
L. S. and E. B. Cushman	858,707
J. T. Lagergren	858,726
R. Varley	858,928
T. W. Hendry	859,383
D. W. Williams	859,474
F. Lamplough	859,501
B. McInnerney	859,510
E. Crowe	859,746
W. R. Smith	859,852
J. Gunther	859,940
H. Kastrup	860,547
N. Crane	860,732
E. Franklin	860,851
N. Crane	861,205
C. W. Weiss	861,411
E. S. Smith	861,614
A. N. Parnall	861,673
J. Croft	861,711
C. Jacobson	861,729
L. Paschall	861,763
R. Varley	861,921
F. R. White	862,363
F. W. Bacon	862,377
G. Cornilleau	862,448
C. I. Longenecker	862,568
O. S. Benckendorf	862,603
J. L. Tate	862,677
L. Boudreaux and L. Verdet	863,142
H. Stoltenberg	863,234
J. G. Ennis	863,838
G. E. Turner and H. C. Fricke	864,049
H. A. W. Drechsler	864,086
H. C. Fricke and G. E. Turner	864,143
C. H. Morgan	864,249
J. Palmer	864,253
J. J. Leary	864,313
H. G. Wood	864,504
L. Wottring	864,586
A. E. Wolcott	864,818
H. Charles	864,830
E. J. Woolf	864,877
C. Brizzolara	865,009
C. J. Mundhenk	865,202
H. Pollard	865,267
R. Varley	865,663
J. W. Burkett	865,677
E. Moore	865,972
C. R. Daellenbach	866,002
A. Rollason	866,069
R. Varley	866,241
H. F Fullagar and J. F Bottomley	866,352
P. F. Thomas	866,538
V. Jahob	866,654
O. Podhajsky	867,075
M. C. Kessler	867,279
J E Aue	867,565
B. Botkowski	867,696
C H T. Alston	867,777
A Bayer	867,782
A. Rollason	868,017
N Macbeth	868,202
H Sohnlein	868,301
H. M Neer	868,689
H Dock	868,765
W K Bassford	868,834
M Fischer	868,978
O. Roberts	869,021
W L Morrow	869,253
R W. Powell and C. F. Norton	869,393
R. Varley	869,601
J D Anderson	869,611
J. F. Duryea	869,887
E. J. Stoddard	869,991
A. R. and F. S. Welch	870,065
D. Libby, Jr	870,240
J. J. Hogan	870,559
A. J Frith	870,720
T S. James and T. H. Wilson	870,966
P. R. Bissell	871,319
J. Houlehan and W. C. Mayo	871,508
J. Pollock and W. F. Leibenguth	871,523

C. E. Van Auken	871,539
A. Rollason	871,632
L. T. Gibbs	872,336
A. G. Griswold	872,342
A. Campbell	872,497
F. Moser	872,571
E. A. Watts and E. G. Morrison	872,598
A. M. Brown	873,493
H. S. Anderson	873,650
L. E. Thompson	873,808
E. H. Cleft	873,840
H. Grade	873,857
F. Lyst	873,952
B. A. Slocum	873,963
O. H. Shroyer	874,122
W. von Oechelhaeuser and C. Stunbecker	874,369
A. J. Spicer	874,450
G. J. Altham	874,920
J. B. Hoover	875,077
H. Soeldner (reissue)	12,635
O. Gassett	875,256
G. W. Stanley	875,297
O. Podhajsky	875,378

1908

A. A. Longuemare	875,716
E. Sturke	875,865
C. T. Litchfield	875,938
J. E. Gilson	875,991
P. C. Lawless	876,003
W. A. Salter	876,020
H. A. Miller and F. M. Adamson	876,472
F. C. Gordon	876,870
W. H. Hooper and F. S. Hutchins	876,878
P. F. Schryer and D. C. Stover	877,378
W. L. Boyer	877,483
A. H. Goldingham	877,500
H. R. Palmer	877,730
W. H. Ash	877,753
H. W. Adams	877,818
P. Daniel	877,834
C. L. Edwards	878,364
O. Minton	878,411
R. S. Thompson	878,578
C. I. Longenecker	878,647
M. G. Voigtlander	878,694
W. H. Newbrough	878,824
W. T. Maxwell	878,888
F. P. Carrier	878,936
J. Braunwalder	879,512
J. S. Benson	879,726
C. F. Pearson	879,837
C. H. McClintock	879,884
C. M. Fox	879,954
H. G. Underwood	879,989
J. D. Hay	880,024
E. J. Boyler	880,503
M. L. Wood	880,704
J. S. Losch and G. H. Gerber	881,189
E. J. Woolf	881,214
H. A. Hettinger	881,582
J. V. Rice, Jr.	881,592 881,593 881,594
T. A. Sammons	881,623
T. Veitch	882,221
A. G. Melhuish	882,401
G. G. Forester	882,496
F. H. Walker	882,597
J. V. Rice, Jr.	882,716
C. O. Carlson	882,812
C. B. Kurtz	883,207
L. G. Sabathe	883,240
G. A. Beaudet	883,511
J. H. and J. H. Birch	883,688
H. L. F. Trebert	884,053
F. F. Miller	884,402
C. R. Radcliffe	884,853
P. Schwehm	884,995
F. Reichenbach	885,520
W. H. Frost	885,598
C. Griswold and S. G. Averell	885,921
C. R. Bryant	886,184
C. J. Mundhenk	886,235
E. L. Vervoort	886,279
W. R. Harris	886,500
J. B. Knickerbocker	886,519
J. Sulzer	886,662
K. Nicoll	886,846
H. T. Dunbar	887,237
H. A. and J. C. Prescott	887,345
W. J. McVicker	887,502

S. H., F. H., and W. G. Heginbottom	887,633
P. A. Sharpneck	887,703
H. D. Baird	887,749
W. R. C. Wakley and R. Parsons	887,988
E. Ruud and C. Regenbogen	888,196
H. O. Westendarp	888,282 888,374
R. J. Rennie	888,533
W. E. Dow	888,597
D. Fergusson	888,794
A. Knox	888,909
D. Roberts and C. James	889,044
G. C. Bourdereaux	889,193
W. K. Andrew	889,886
F. M. Ashley	889,887
F. H. Arnsburger	890,208
C. A. Myers, F. W. Haas, Jr., and A. A. Myers	890,247
J. E. Gilson	890,270
W. J. Griffith	890,272
P. S. Claus	890,335
P. M. MacKaskie	890,522
A. P. Schmucker	890,532
A. B. Wittmann and G. L. Rork	890,546
R. E. Olds and H. T. Thomas	890,571
R. Diesel	890,620
H S. Hart	890,643
J. D. Macpherson	890,673
C. M. Stroud	890,815
H. Junkers	891,078
J. H. Pierce	891,366
W. B. Potter	891,368
H. H. Benson	891,394
A. G. Scholes and G. Gibson	891,638
M. A. Trow and F. J. Brummer	891,643
M. V. Robinson and J S. Seybert	891,735
M. Blieden and J. H. Davies	891,901
F. W. Brady	891,903
C. Echard and R. S. Paul	892,035
F. A. Feldkamp	892,037 892,038
N. W. Hartman	892,049
W. R. Webster	892,199
G. B. Hakins	892,253
J. H. Cogswell	892,501
L. S. Nash	892,609
A. Sletten	893,026
W. O. Covey	893,056
F. J. Crouch and C. P. Church	893,058
W. F. Schleichter	893,268
F. Ottesen	893,359
J. A. Torrens	893,400
S. I S. Ringi	893,656
J. F. Denison	893,712
L. R. O'Neill	894,225
F. C. Avery	894,568
C. R. Greuter	894,775
J. C. Peache	894,978
C. Burgess, Jr	895,155
O. Kelly	895,184
C. R. Radcliffe	895,194
W. L. Morrow	895,286
H. C. Bailey	895,328
H. A. Johnston	895,466
C. O. Headstrom	895,754
F. A. Dobbins	895,982
L. S. Watres	896,183
H. Lemp	896,305
G. B. Petsche	896,318
D. B. Gardner	896,375
J. Tinlin	896,485
D. Clerk	896,893
R. Herman	897,532
T. W. Heermans	898,103
G. S. Hill	898,107
H. J. Leighton	898,117
D. Roberts	898,139
C. O. Lake	898,230
M. M. Maher	898,243
C. N. Scott	898,271
V. F. Carpenter	898,317
H. Benoist	898,427
K. E. Schriber	898,512
C. R. Piggens	898,678
W. C. Plank	898,779
E. A. Nelson	898,913
A. W. Daniel	898,974
C. E. Shadall	899,136
W. Rabsilber	899,186
T. W. Hendry	899,216
J. B. Schmidt	899,265
W. K. Andrews	899,498
F. Reynolds	899,618

R. Varley	899,770
J. T. Dickson	899,715
S. A. Reeve	899,842
C. A. Clark	900,083
R. W. Godfrey	900,518
A. W. Cottrell and W. A. Moore	900,668
W. H. McNutt	900,765
F. A. Thurston	900,798
J. Clay	901,278
A. Schieferstein	901,745
A. E. Remick	902,450
C. Cuno	902,522
H. N. Edens	903,182
L. Burnham	903,269
W. Remington	903,774
O. G. Simmons	903,902
D. Roberts	904,086
G. A. Goodson	904,196
E. Korting and J. Kritzler	904,267
E. A. Nelson	904,556
E. Rathbun	904,562
H. C. L. Holden and G. K. B. Elephinstone	904,616
L. Le Pontois	904,624
	904,625
G. Enrico	904,855
J. Hutchings	904,961
H. Lee	904,974
G. B. Petsche	905,224
J. W. Smith	905,379
A. F. Towle	905,389
P. D. Johnston	905,434
H. Sohnlein	905,598
W. R. Webster	905,611
E. Apperson	905,625
R. A. Maples	905,727
A. J. Miller	905,733
R. A. Maples	905,822
C. J. Montgomery	905,823
H. M. Neer	905,911
C. A. Johnston	906,030
H. Charles	906,105
J. S. Cottrell	906,111
G. Westinghouse	906,177
P. V. Rehill	906,288
E. H. Williams	906,345
H. Dock	906,393
H. Saurer	906,663
S. R. Du Brie	906,671
J. E. J. Goodlett	906,703
F. C. Mason and G. L. Sintz	906,729
C. S. Cole	906,773
J. W. Smith	906,949
O. Grimm	907,039
H. C. Suckert	907,196
W. O. Worth	907,669
C. I. Longenecker	908,112

1909 to Oct. 1st

C. W. Weiss	908,527
O. E. Barthel	908,641
L. A. Frayer and C. O. Howard	908,657
L. P. Fosnot	908,764
E. M. Weinat	908,916
L. P. Fosnot	909,075
F. W. Brady	909,531
C. R. Daellenbach	909,558
J. A. Prestwich	910,018
C. G. Dean	910,181
G. M. S. Tait and C. Ellis	911,345
H. Lentz	911,825
G. L. Lyon	911,891
T. Matson	912,012
A. O. McCollum	912,150
D. H. Thompson	912,332
C. E. Duryea	912,546
C. M. Steely	912,751
J. C. and W. C. Strickler	913,070
J. E. Patterson	913,156
J. E. Friend	913,635
G. Huscher	914,281
C. M. Leech	914,292
J. G. Willet	914,366
C. H. Thordarson	914,532
A. L. Galusha	914,566
R. McMyers	914,864
R. Varley	915,389
	915,390
	915,391
	915,639
W. J. Wright	915,717
D. J. Cartwright	916,103
L. T. Bassett	916,972
C. Sella	917,165
W. H. Frost	917,283
J. F. Duryea and W. M. Remington	917,722
H. A. Long	917,780

C. W. Snyder	918,211
L. G. Sabathe	918,704
H. H. Whitehead	919,103
C. J. Farrar	919,842
M. Tsckimperle	919,980
W. Heckert	920,056
J. J. McIntyre	920,167
J. W. Smith	920,405
H. C. Bailey	920,411
M. Berliet	920,417
J. Zagora	920,515
G. R. Bott and K. Langnickel	920,816
O. P. Ostergren	920,989
C. W. Weiss	921,035
C. E. Mead	921,264
J. C. Peache and M. H Robinson	921,649
B. M. Aslakson	921,657
T. B. Doolittle	921,679
J. L. White and J. B. Polo	921,769
G. H. Marquardt	922,009
S. A. Reeve	922,509
B. F. Sherbley and W. Moller	922,528
C. D. McClintock	922,613
M. B. Crist	922,673
T. D. Kelly	922,911
E. Westman	922,987
E J. Gulick	923,046
O. Lietzenmayer	923,054
R. Nessler	923,069
H. J. Wegner	923,093
R. W. Coffee	923,491
H. H. Cutler	923,496
J. G. A. Kitchen	923,536
E. Munsch	923,562
C. G. Sprado	923,591 923,594
W. E. Struss	924,116
R. A. Reynolds	924,382
R. D. Cody	924,634
H. M. Cramer	924,640
L. E. Fish	925,766
S. A. Reeve	926,134
W. H. Hollopeter	926,564
C. C. Coffey, T. Pfennighausen and E. A. Robinson	926,641
H. Greer, Jr	926,651
J. and F. O. Peterson	926,892
L Petterson	927,004
J L. Bogert	927,103
E. W. Graef	927,233
W. H Rozier and S. C Igou	927,681
H. M. Yager	928,299
H. H. Simon	928,405
G B Selden	928,803
E Berliner	928,842
J A. and J. Charter	928,939
B. G Harley	928,968
W. C. Thornhill	929,262
C. G Hess	929,429
A. F. Clarke	929,554
W. A Hansen	929,588
I. G. Neuber	929,622
J. J. Kulage	929,769
W. Burnell	929,829
C. T. Brown	930,347
G. Green	930,372
H. H. Dow	930,943
G Honold	931,066
W. F. Beaton	931,176
A. S Krotz	931,319
E. A. Rundlof	931,346
G. L. Crook	931,389
C T. Wade	931,531
H W. Beach	931,837
E M Turner	931,976
C. H Sergeant	932,184
V Barreto	932,239
L. E Lemperiere	932,419
C. L. McHenry	932,804
P. J Grouvelle and E. H. Arquembourg	932,860
F. W. Reeves	933,109
A. J. Gifford, J. J. Burns, and B. S. T. Bishop	933,246
W. G. Macomber	933,316
N. McCarty	933,325
J. Illy	933,709
D. H. Coles	933,960
H. Schaake and J. T. Cowie	934,842
J. T. Cowie	935,091
N. M. Hopkins	935,154